

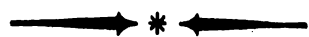
MEN OF RUSSIAN SCIENCE

Prof. B. B. KUDRYAVTSEV

THE LIFE AND WORK
OF
MIKHAIL VASILYEVICH
LOMONOSOV



FOREIGN LANGUAGES PUBLISHING HOUSE
Moscow



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OF RUSSIAN
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M. V. Lomonosov (engraving by Vortman)

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INTRODUCTION

The history of mankind knows many examples of people endowed with numerous talents. Leonardo da Vinci, the great Italian painter, was at the same time a gifted scientist. The same may be justifiably said of the great German poet Wolfgang Goethe. Alexander Porfiryevich Borodin was simultaneously a physician, an outstanding chemist, and a remarkable musician.

Many more examples of gifted men might be mentioned, but it would be impossible to find among them a man as richly endowed by nature as was Mikhail Vasilyevich Lomonosov, the great Russian scientist.

It would be difficult to enumerate all the branches of science and art that the genius of Lomonosov has illumined. Alexander Sergeyevich Pushkin, the great Russian poet, wrote that "combining extraordinary strength of will with extraordinary strength of mind, Lomonosov embraced all the branches of education. A thirst for knowledge was the overpowering passion of this passion-filled soul. Historian, rhetorician, mechanic, chemist, mineralogist, artist, and poet, he experienced everything and fathomed all."

It should be remarked that Lomonosov's versatile activities and his genius were inspired by the stormy

epoch of reforms in Russia, the epoch connected with the activities of Peter I.

Lomonosov occupies by right one of the first places among people of whom the whole cultured world is proud. While recognizing the universal significance of his genius, we must note at the same time the profoundly national character of his creative work. "The history of Russian science," wrote S. I. Vavilov, the late President of the Academy of Sciences of the U.S.S.R., "shows that the characteristic feature of its men of genius has always been the extraordinary scope of the problems they undertook and of the results they achieved, which were always based on amazingly firm grounds and reality and, at the same time, on simplicity in approaching solutions. These features and this style of work, which we meet in Mendeleyev and Pavlov, received extraordinary expression in Lomonosov."

The combination of science with practice, with problems of everyday life, was an organic feature of Lomonosov's work. "Science shows the way to the industries; industries hasten the development of science. Both work hand in glove for the public welfare," he wrote, and reiterated this idea in all his creative work. Research into the properties of gases helped him to establish the laws of ventilation in mines; experiments in chemistry—to elaborate the technology of producing stained glass; geographical investigation—to discover the northern passage to India, and so forth.

The motive force that guided all his activities, no matter how varied they were, was the desire to serve his Motherland. "What joy it is to work for your country's good!" he would exclaim with all his heart.

Now, when we look through his writings and the plans that untimely death prevented him from fulfilling, we can clearly see that the thought of the people's happiness was uppermost in his mind throughout his life.

A man of great passion, he gave all his energy to science and art, which, in his opinion, were designed to serve mankind.

The life of Lomonosov is, indeed, deserving of imitation!

He was a man fervently devoted to science. His selfless struggle for science is a striking example of the heroic features of the great Russian people.

This little book tells us about the life and work of Mikhail Vasilyevich Lomonosov, who was a brilliant scientist, a great citizen, and a true son of the Russian people.

science serve the needs of industry and promote the development of the national economy.

Everything young Mikhail saw aroused a thirst for knowledge unusual in a boy of his age. Whenever he returned from a voyage he would get down to his books. He learned to read at an early age and soon knew by heart the few books he could get. However, as these books dealt with ecclesiastical matters, he did not find in them the answers to the questions he was interested in.

With great difficulty he managed to get some of the few secular books that were in circulation in those days. Of these *A Slavonic Grammar* by Smotrisky, and Magnitsky's *Arithmetic* opened to the boy a world of knowledge he had never known.

He was particularly influenced by Magnitsky's *Arithmetic*. This book was unlike the arithmetic textbooks we now have. Besides the simplest rules of mathematics, the simple information on physics, geometry, navigation, astronomy, and so on, that it contained was set forth in a manner which made independent study easy. This book was a sort of encyclopaedia of the time.

Reading these books was a great joy to Mikhail, but he had to pay a high price for this joy.

He was unhappy at home. His mother, Elena Ivanovna Sivkova (the daughter of a deacon from a neighbouring village), died when he was a baby. His father married again soon after her death. In 1724 he married a third time after the death of his second wife.

Mikhail's second stepmother took a dislike to him, and tried to bring about a quarrel between him and his father. Seeing the boy's love for reading, she did everything she could to stop him and to convince his father that Mikhail was only seeking a pretext for shirking work. Many years later Lomonosov wrote: "My father was a very kind man by nature, but he had been brought up in extreme ignorance, and my wicked and jealous step-

mother tried in every way to rouse his anger against me, telling him I was always wasting time over my books. Therefore, very often, when I wanted to read or study what I could, I had to hide in some lonely place and endure cold and hunger...."

His stepmother's persecution, which was making life unbearable at home, and his insurmountable striving for knowledge, which could not be satisfied there, forced Mikhail to make up his mind to leave his family.

In the winter of 1730 Lomonosov set out for Moscow and reached the city in January 1731.

At that time there was only one school there that could pass as an institution of higher education. This was the Slavonic-Greek-Latin Academy at the Zaikonospassky Monastery, which was founded in 1684. It was situated in former Nikolsky Street, behind "Icon Row."

The Academy had eight classes: four lower, two middle, and two higher. In the four lower classes the students were taught Latin, the Slavonic language, history, the catechism, and arithmetic. In the middle classes they studied poetry and rhetoric, and in the higher classes—philosophy and theology. Many of the students of this Academy subsequently became widely known. Among them were L. F. Magnitsky, the first "Russian teacher of mathematics," A. D. Kontemir, a remarkable Russian satirist, and V. K. Tredyakovsky, the initiator of a new trend in versification. Somewhat later the Academy was finished by Vasili Bazhenov, the brilliant architect.

Lomonosov's first years of study were difficult. He himself described them thus: "On the one hand, my father, who had no other children, said that I, his only son, had left him, and that the wealth he had accumulated for me by the sweat of his brow would be wasted by strangers after his death. On the other hand, I suffered indescribable poverty: three kopeks constituted my day's allowance.

I could not buy more than a piece of bread and some *kvass*, as I had to pay for paper, boots and other needs.... On top of it all small schoolboys shouted, laughed, and pointed to me with their fingers: 'Look at the fool who has come to study Latin at the age of twenty....'

Nevertheless Lomonosov studied at the Academy with great diligence and, thanks to his unusual natural ability, his progress was astounding. In his first year he completed the course for two classes and was passed to the third. He spent all his free time in the library, eagerly reading books.

Besides religious books the library had Russian chronicles and books on physics, philosophy, and mathematics.

The Greek language was not taught at the Academy, but Lomonosov studied it independently, and this enabled him to read the beautiful works of the poets of classical antiquity and to study Byzantine culture.

Many years later his knowledge of Church-Slavonic, Greek, and the language of the Russian chronicles helped him to establish the independent character of the Russian language and the originality of Russian national culture.

Lomonosov studied also in other Moscow libraries, where he found books in many languages. His favourite was the so-called "Print-Shop Library," which had books in the Greek, Latin, Polish, Slavonic, German, and other languages.

The knowledge, especially of Latin, that students acquired in the first two classes was at that time necessary in order to study science, as nearly all scientific books were written in Latin. Lomonosov's splendid knowledge of Latin, which he gained at the Academy, proved very useful. At the Academy he became acquainted with some ideas of a new philosophy. Though scholasticism was the basis of teaching, yet the text-book on philosophy

by the talented philosopher F. Lopatinsky, which Lomonosov used for his studies, contained ideas that were progressive for that time. For example, this book stated that a philosopher "wishing to learn the naked truth does not rely upon other people's words; it is natural for a philosopher to trust more to reason than to the words of those who have authority. . . . Truth is open for all and is not yet exhausted; much of it remains for future generations, too. . . ."

Such ideas, however, were not typical of the teaching at the Academy, and, on passing to the higher classes, Lomonosov became less and less satisfied with it. Natural science, which interested him, was not taught. Students were engaged in solving such "important" questions for science as "where were angels created?", "was there a thornless rose in paradise?" or "why have women no beards?", etc.

Eager to obtain the knowledge he sought, Lomonosov applied to be sent to the Theological Academy in Kiev, which at that time ranked as the second most important institution of higher learning in Russia. But there, too, he failed to find what he had been seeking since boyhood. Instead of physics and chemistry he had to study the works of priests. One year at the Academy was enough to show him that he was only wasting his time, and so in 1734 he returned to Moscow.

In 1735 he was in the senior class at the Academy in Moscow. There seemed nothing left to do but to graduate and become a priest. But doubts assailed the young man. Was that the life he had hoped for when he left his home? Was it for this that he had endured cold and hunger? Where were the answers to the questions which neither the teachers at the Academy nor the books he had read could give?

These tormenting questions were solved quite unexpectedly. .

At the end of the summer of 1735 he was summoned to an interview with Stefan Kalinovsky, the Rector of the Academy. Lomonosov spent a sleepless night vainly trying to guess the outcome of this mysterious summons. Would he be offered a benefice somewhere in a remote corner of Russia? Or was it the old issue about getting into the Academy under false pretences? He had called himself "the son of a nobleman from the town of Kholmogori," for he had known how strictly the rules of the Academy forbade the admittance of the "children of serfs and peasants."

True, he had been forgiven when he had confessed this and had been permitted to continue his studies, because of the excellent progress he was making. But he was worried just the same. There was no telling how things would end if it had been decided to re-examine the case.

He went to see the Rector with a heavy heart. How much greater was his joy then when he learned that, among other best students, he was to be sent to Petersburg to continue his studies at the University. At last his childhood dream had come true—he was on the broad road to knowledge.

Development of industry in Russia in the eighteenth century was mainly based on a growing utilization of the country's natural wealth. Industry and agriculture aimed directly at the exploitation of the forests, minerals, and land. This demanded of the scientists of that time a thorough study of the country's natural resources. Similar demands were being made by the expanding trade that was linking up the vast spaces of Russia into one economic unit. Quite natural, therefore, was the abundance in eighteenth-century Russian scientific literature of descriptions of nature, mineral resources, and the economic features of separate districts of the country. The



Zaikonospassky Monastery in Moscow, which was the home of the Slavonic-Greek-Latin Academy



Academy of Sciences in Petersburg (from an engraving of a picture by M. Makhayev)

accounts of the scientific expeditions of that time are summaries of a complex combination of astronomic, geographical, geological, geobotanical, economic, and other surveys relating to various spheres of knowledge.

The development of natural science in Russia in the eighteenth century is closely connected with the economic development of the Russian state under Peter the Great.

"When Peter the Great, having to deal with the more advanced countries of the West," J. V. Stalin said, "began feverishly to build factories and workshops in order to supply his armies and to strengthen the defences of the country, it was a peculiar attempt on his part to escape from the grip of backwardness."

Towards the close of Peter the Great's reign the country had undergone a radical economic change. Russia had more than 200 industrial enterprises, some of which were quite large for that time. The Russian foundries were turning out about 24,000 tons of pig iron annually.

Peter strove to amass "information on all that nature was producing" in the huge Russian expanses. He sent out numerous expeditions, giving each a different task. One had to "seek a route to India by land and water, and to describe and chart it." Another had to find out if "Asia was joined to America," and, if so, where namely, and so forth.

Mechanics, mathematicians, and astronomers were needed to carry out the reforms Peter planned, to build ordnance factories, a fleet, and to develop the industry. Peter personally directed the publication of scientific literature, even reading some of the manuscripts before they were printed. The church disapproved of Peter's activities. It could not forgive him for "establishing schools of mathematics and academies of ungodly sciences."

Peter clearly realized that theological seminaries and academies could not become centres for the development

and dissemination of natural sciences which were necessary to the state, and he decided to organize an Academy of Sciences in Petersburg. He personally directed the organization of this Academy and drew into its work the most prominent naturalists of Europe.

Peter wanted the Academy to be simultaneously a higher scientific society and an institution of learning. Its educational establishments consisted of a secondary school and a university. Members of the Academy were called professors, who had to teach at the university besides carrying on their scientific work. The secondary school had to prepare young men for the university. As efforts to enroll a sufficient number of students for the secondary school and university proved unsuccessful, Baron Korf, the "High Commander of the Academy," appealed to the Senate in 1735 to have the monasteries and ecclesiastical academies send adequately prepared young men to the university. The request was granted, and it was for this reason that the Rector of the Zaikonospassky Academy was ordered to send to Petersburg 20 of his most capable pupils. He was able to select only 12 young men who could meet the requirements. Among them, as one of the best, was Mikhail Lomonosov.

When he arrived in Petersburg, Lomonosov was immediately enrolled into the university and began to study German, Latin, mathematics, rhetoric, geography, history, and dancing. The mathematics course included physics.

Here Lomonosov's aspirations finally began to be realized: the subjects he had wanted to study all his life were now before him, and it was only natural that he devoted all his time to them. Very soon his outstanding capabilities were noticed, and it was due to this that his path in life underwent yet another sharp twist. Before a year was out he and two other of the most capable students were sent to study abroad.

This trip had its prehistory. In those years the Academy was fitting out numerous expeditions to study the country's natural resources, and planned sending one to investigate Kamchatka. Such an expedition required a chemist with mining experience, but there was no suitable candidate for the post in the Academy, and efforts to enlist a foreign chemist failed. This prompted its decision to send students of Petersburg University to Freiberg, Germany, to study mining under Henckel, a well-known metallurgist of those days. Thus G. U. Raizer, D. I. Vinogradov, and M. V. Lomonosov were chosen as best suited for the purpose.

But in order to let the students thoroughly master metallurgy, it was decided that they should first go to Marburg University to study physics, mechanics, mathematics, chemistry, and the most important languages under Christian Wolf, a prominent philosopher.

Before leaving, the young men were given detailed instructions on their future duties. The instructions said that they were to be "good-mannered, decent in behaviour, and diligent in the pursuance of their studies. To work hard for the attainment of the desired results in learning chemistry and mining and, moreover, to study natural history, physics, geometry and trigonometry, mechanics, hydraulics and hydrotechnique..." Besides this "they were to do their best to learn the Russian, German, Latin, and French languages so as to be able to write and speak them fluently and, in addition, they were to be diligent in the study of drawing."

On September 8, 1736, Lomonosov boarded the *Ferbotot*, the ship that was to take him to Travemünde. But the voyage began unfavourably. The weather deteriorated as soon as the vessel put out to sea and the familiar outlines of Kronstadt rapidly faded. Huge waves tossed the *Ferbotot* as though she were a cork. The skipper's frown deepened as he debated with himself

whether or not to turn back to Kronstadt and to stay there until the storm spent itself. Caution won and the vessel was ordered back to port.

The days dragged by tediously as the travellers waited for the weather to clear. It was only on September 19 that the *Ferbotot* set out, arriving safely in Travemünde on October 16, 1736. After three days' rest at Lübeck the students went on further, posting through Hamburg, Minden, and Kassel. This was Lomonosov's first visit to Germany and he looked with interest at the towns and villages. Marburg was finally reached on November 3 without any special adventures, after a journey of six weeks.

The three young men talked of many things during their journey. They spoke animatedly about the life around them; it was so different to what they had seen till then, and they wondered how they would be received by Christian Wolf. There were rumours that Wolf knew Peter personally. When Peter was organizing the Petersburg Academy it was Wolf who helped him. They knew, too, of Christian Wolf's great authority in his own country, and realized that it was not by chance that they were being sent to study under him.

The more pleasant, therefore, was the warm welcome awaiting them in Marburg.

Lomonosov highly appreciated Wolf's friendliness and followed his lectures very enthusiastically. He especially admired Wolf's mathematical teaching method. This method, characteristic of his system, introduced clarity into the presentation of the most complex subjects. Young Lomonosov there and then resolved to apply this method if ever he had occasion to teach. The way mathematics can help people to understand and develop the sciences, he argued, "may be seen from the example of certain branches of natural sciences such as hydraulics, aerometry, optics, and others, which have been successfully

elaborated mathematically; all that was obscure, dubious and wrong in these sciences has been made clear, true and obvious by mathematics."

Life changed strikingly for the Petersburg students. After the bitter privations and comparatively strict regime at the Zaikonospassky Academy in Moscow and at the university of the Petersburg Academy, Lomonosov found himself living the rough, boisterous life of eighteenth-century German students. Many things that would seem intolerable to us today were quite normal then. Here is a description by a Marburg chronicler of a university celebration: "About 500 people dined in the hall; the students made merry to their hearts' content, but apart from the smashing and breaking of all the glasses, bottles, tables, benches, and windows, there was not the slightest accident or disorder."

Lomonosov was now much better off materially. He received 30 times more money than at the Zaikonospassky Academy and, besides, he could always borrow some whenever necessary.

Lomonosov was very sociable and could not, of course, remain indifferent to the life around him. He drank deeply of the atmosphere at Marburg University. We can only wonder that the madcap life of his new comrades, to which he gave its due, did not hinder his diligent study nor prevent him getting from his teachers all the knowledge they could give.

Lomonosov took less than a year to get a fluent knowledge of German.

The report on his studies that he sent to the Academy in 1738 under the elaborate heading, as was the custom in those days, of *Specimen of My Knowledge of Physics: on the Conversion of Solid Substances into Liquids, Depending on the Movement of the Liquid Present*, contains some of the ideas that later permeated all his work. Among them is the idea that most of the properties of

various bodies can be explained by the movement of their smallest parts. His bold defence of this idea in after years was viewed with disfavour by official science in Europe.

Two features that distinguished his scientific work clearly manifested themselves in this thesis: he proved his statements with both irreproachable logic and extraordinary simplicity.

Together with this first work in physics Lomonosov sent a translation in verse of a French ode by Fénelon.

The following year he forwarded another report, from which it was clear that by that time he had made a thorough study of mechanics, hydraulics, aerometry, hydrostatics, and physics.

He supplemented this report with a thesis *On the Variety of Compound Substances Consisting in the Cohesion of Corpuscles. An Essay Written by Mikhail Lomonosov*. This thesis shows signs of profound individuality. Though he mastered his teacher's method, he did not become an imitator. The idealistic and reactionary side of Wolf's philosophy, closely allied to that of Leibnitz, was organically alien to him. In this essay he gave lucid display to the idea of studying the material constituent parts of bodies in order to understand and explain their properties. Lomonosov worked to develop this idea to the end of his life.

The thesis was received in Petersburg and read by the academicians, and there is ground to believe that it was highly appraised by them.

The three years' stay at Marburg was very productive. Here Lomonosov broadened his knowledge of philosophy and of the natural sciences, and became acquainted with the achievements of science in Europe at that time. This prepared him for further scientific and practical work.

Lomonosov always critically approached anything he learned and it was amazing how unerringly he determined what was true and deserving, and what was false and superficial. In all his later scientific work Lomonosov always courageously went his own way, never changing his views, even when they differed from the opinions of the authorities most respected by him.

Christian Wolf grew very fond of his brilliant pupil, and prized his talent highly. In the character-report he gave of Lomonosov, he said: "Mikhail Lomonosov, a young man of great ability, has, since his arrival in Marburg, regularly attended my lectures in mathematics, philosophy, and especially in physics. He is very eager to acquire thorough knowledge, and I have no doubt that, in due course, if he continues to apply the same devotion to his studies, he will be able, on his return to his country, to work for her benefit, as I sincerely hope."

Even short-sighted people, who perhaps could not appreciate the genius of Lomonosov, paid tribute to his brilliant talent. Justin Duysing, a professor of chemistry, writing about him, said: "The gifted and worthy young man, Mikhail Lomonosov, student of philosophy ... attended with untiring diligence my lectures in chemistry in 1737 and, in my opinion, has considerably profited by them."

After completing their studies at Marburg, Lomonosov and his comrades went to Freiberg to study metallurgy under Johann Henckel. They arrived there on July 25, 1739.

Lomonosov's stay in Freiberg turned out badly. Very soon he fell out with Henckel, and this gave rise to mutual recriminations. Henckel complained of Lomonosov's ill-temper and of his unwillingness to carry out orders. Meanwhile, in a letter to the Academy Lomonosov complained that at the lectures "most of Henckel's experiments failed because of his own clumsiness. Our diaries are filled with descriptions (which he dictated with

an admixture of vulgar jokes and empty prattle) of such unhappy incidents. At the same time he despised all rational philosophy and once, when, at his request, I began explaining the cause of chemical phenomena, he ordered me to stop immediately and, with his usual impertinence, began to make fun of what I had said, calling it 'castles in the air.'"

To understand the disagreement between Lomonosov and Henckel, it must be remembered that in Marburg Lomonosov had been imbued with the spirit of advanced science. There he had read the works of Newton, come to love philosophy founded on experiment, and became firmly convinced that "a true chemist should be both a theoretician and a practitioner and . . . that those engaged in practical work only are not true chemists."

According to Academician Vernadsky, the outstanding Soviet mineralogist and geochemist, Henckel "was a chemist of the old style, without a trace of original thought. He did, however, make some correct particular observations. . . . After what he had seen and learned in Marburg it seemed to Lomonosov now that he was in an environment that was fifty years behind times, and that from the interests of the new and actively progressive trend in the intellectual life of Germany he had suddenly plunged into the musty atmosphere surrounding a blundering scientist, long retired from scientific work."

Differences developed into an open quarrel. Lomonosov stopped attending Henckel's lectures. And when, finally, he grew completely disappointed in his teacher as a scientist, and saw that a further stay in Freiberg would be profitless, he decided upon a risky step.

He arbitrarily left the town in May 1740, after studying there for less than a year. As he had no money he decided to go to Baron Keizerling, the Russian Ambassador and former President of the Academy of Sciences. But

the latter proved difficult to find. Lomonosov went to Leipzig, hoping to meet Keizerling there. "When I arrived in Leipzig on May 19," Lomonosov wrote, "I learned to my distress and sorrow that he had gone to Kassel to attend the wedding of Prince Friedrich.

"In Leipzig I found some kind friends from Marburg, who offered me their company to Kassel. In Freiberg I had nothing to eat, nor anything more to learn, because I had mastered chemical analysis and had also completed the course in chemistry. In Kassel to my great regret I learned that there, too, nothing was known about the ambassador's whereabouts. My position was desperate. I did not know where to find the baron, and so I thought it best to go to Petersburg if in Holland I would not be helped by Count Golovkin (then Russian Ambassador to Holland). At first I went to Marburg to borrow some money for the journey from old friends. I did not venture to presume upon Mr. Wolf, when I learned from him that he had received the balance of his fee from Petersburg only a few weeks ago. Besides, I remarked his unwillingness to meddle in my case. And so from Marburg I travelled to Frankfurt, and from there, by water, to Rotterdam and The Hague. Count Golovkin flatly refused to help me or to concern himself with the affair in any way. After that I went to Amsterdam, where I found some merchants I had known in Archangel. They strongly advised me not to return to Petersburg without official permission, and described the direful perils and misfortunes that awaited me should I venture on this step; this forced me to return to Germany. And even now I am appalled every time I think of the danger and hunger that had dogged me on that journey. At present I am staying incognito with friends in Marburg and spend my time perfecting my knowledge of algebra as I intend to apply it to theoretical chemistry and physics. In the meantime I am consoling myself with the thought that I have been to famous cities, spoken to some

skilful chemists, seen their laboratories and had a look at the mines in Giessen and Siegen."

In the description of his journeys, Lomonosov omitted the fact that in Marburg on June 6, 1740, he married Elizabeth Zilch, the daughter of a churchwarden.

Nor did he give a detailed description of the dangers he had been exposed to. And they were quite a few! One of them is worth describing. When he gave up his idea of going to Russia, Lomonosov returned to Germany from Amsterdam, making his way to Marburg on foot. Twilight was falling when, tired, hungry, and penniless, he reached a wayside tavern in a small German village. Although he did not expect to get any supper there, he nevertheless decided to go in for a rest. The door was too low for his giant stature. Bending, he entered a low-ceilinged, neatly-arranged hall and for a moment blocked the rays of the setting sun streaming in through the door. A small group of Prussian hussars were enjoying themselves at one of the tables. One of them, evidently an officer, admiringly eyed Lomonosov's massive figure. The king, thought he, would not stint money to have a soldier like that! There was the case of the king's father paying 12,000,000 talers gladly for a regiment of tall soldiers. Realizing that he could profit by this the officer cordially invited Lomonosov to join his company. Lomonosov, who had eaten nothing since morning, quickly grew tipsy and could hardly follow the officer's unceasing praises of the life of Prussian hussars. Overpowering sleepiness began to get hold of Lomonosov, but the officer went on pouring more and more wine into his glass. Finally, his head slowly sank to the table and he fell fast asleep. In the morning he could hardly recall the night's happenings. He was seized with misgivings, however, when he remembered the unusual cordiality of the Prussian officer. As far as he knew Prussian officers, such behaviour was unusual. He felt his neck apprehensively. . . . Yes, of course, there it

was—a red neck-tie whose ends the officer had tied somewhere about his ear. So that was what the treat meant! Now he was a recruited hussar in the service of Friedrich, King of Prussia. But no, nothing would make him a Prussian soldier! It was not for this that he had left his home and suffered such privation. The thing to do now was to be careful and not to show that he disliked being one of His Majesty's hussars. Lomonosov pretended he was quite satisfied, and, together with other recruits, was sent to the fortress of Wesel. This cheered him, as the fortress was on the very frontier. In the fortress he did not betray his intention, spent the day merrily and went to bed early. He did that on purpose in order to refresh himself in case an opportunity offered itself to escape during the night. When he awoke the camp was quiet. He stole out in blind darkness and reached the rampart around the fort. Clinging to every uneven spot on the ground, he moved down as slowly as he could in order to drop noiselessly into the water in the moat. Getting safely over this obstacle, he stopped for a moment's rest and crawled further away from the camp. Suddenly he saw before him a second moat. In his excitement he had almost forgotten that Wesel was surrounded by two moats. Another slow descent. He was quite near the water when his hands lost their grip and he fell in. The splash seemed loud in the stillness of the night! His heart sank; he felt its throbbing. Had the splash been heard by the sentry? But all around was silent. The second moat and the stockade were now far behind, and before him lay the open road to the frontier and to freedom. Bending forward Lomonosov sprinted across the field, away from the fortress. He stopped irresolutely after he had covered some ground: what if in the darkness he had taken the wrong direction and was now running not towards the frontier, but away from it? That could not be, he told himself, for he had taken stock of his surround-

ings during the day. And here was the tall pine he had noted! Now the thing was to run; seven *versts* lay between him and the frontier, and the approaching dawn was already lighting up the horizon. The report of a cannon suddenly broke the stillness: his escape had been discovered! Lomonosov ran as fast as he could, the blood hammering at his temples. But he dared not slow down—he knew that now a mounted detachment had been sent out to catch him. He simply had to run! And, mustering all his remaining strength, he ran as he had never run before. He reached the frontier, but continued running for another half-hour through a woods to get as far away from it as possible. He stopped finally from sheer fatigue and, seeing that nothing threatened him now, threw himself on the soft moss and slept soundly till evening. When he awoke he continued his way, passing himself off as a poor student and, at last, safely reached Marburg.

From Marburg Lomonosov sent a letter to the Academy, an extract from which has been quoted above.

In the spring Lomonosov again set out for Holland and from there to Petersburg. He went on alone, without his wife, arriving in Petersburg on June 8, 1741. This brought an end to his studies, which he began at the Zaikonospassky Academy ten years before.

What knowledge had Lomonosov acquired in that time? "In the first place," writes B. N. Menshutkin, the well-known Russian chemist, "besides his perfect knowledge of Russian and Church-Slavonic, he now had command of Latin, German, and French, and could read in a number of other languages. In Marburg he mastered a necessary knowledge of mathematics, philosophy and logic, the physical sciences, especially physics and chemistry, and of such natural sciences as mineralogy and mining and, quite likely, botany and zoology. Then he studied a number of applied sciences, among them various branches of mechanics. In Freiberg he obtained consider-

able knowledge of metallurgy—from the mining of ores to the production of metals and chemical analysis. He studied the production of glass, ceramics, porcelain, and salt, and also navigation, astronomy and geography, not to mention such sciences as rhetoric, grammar, history, political economy, etc.” It may be said that these years of study made Lomonosov “an all-round scientist and practitioner, ready to take up any kind of work.”

When he returned to Petersburg on June 8, 1741, Lomonosov was not given any definite position in the Academy of Sciences. He began his work there by compiling a catalogue of its mineralogical collection, at the same time applying his usual energy to various branches of science.

His unauthorized departure from Freiberg evidently involved no penalty, but the uncertainty of his present official position weighed on his mind.

When, in 1736, Lomonosov and his comrades left for Germany they had been promised that if, while abroad, they attained a thorough knowledge of the sciences they studied and received corresponding certificates, they would, on their return, be made professors extraordinary. Therefore, on January 8, 1742, Lomonosov handed in an application in which he reminded the authorities of this promise. He wrote that during his studies abroad he had mastered physics, chemistry, and mining to such a degree that now he was qualified to teach and to write useful books with new ideas on these subjects. The application was considered and Lomonosov was appointed assistant professor at the Academy with a salary of 360 rubles a year. At that time this money was enough to secure for him quite a comfortable living, but the Academy was so mismanaged that not only the employees but even the academicians were paid their salaries very irregularly.

"I have not received my salary from the Academy," Lomonosov complained, "for nearly a year and have reached extreme penury. And now that I am ill, I have no money to buy either medicine or food, and am quite unable to borrow any." Lomonosov often thought of getting his wife to join him, but his poverty stopped him from taking this step. There were other reasons, too. Hot-tempered, impetuous and straightforward, Lomonosov could not keep aloof from the fierce struggle that was being carried on in the Academy by Russian scientists against foreigners who had taken the management into their own hands.

The Academy was controlled by I. D. Schumacher, who was Counsellor of the Administration and was strongly supported by an influential bureaucratic clique at court. Lomonosov clearly understood that "Schumacher thought it dangerous to encourage Russians to study and to progress in science, and to have them appointed professors." Therefore, Lomonosov, who ardently loved his country, decided "to fight this enemy of Russian science to the end."

He was deeply indignant at the way things were run at the Academy. Much later, he wrote: "It was ridiculous that when Lomonosov had long returned to his own country and was employed at the Academy as assistant professor in the class of physics at a salary of 360 rubles, the office of the Academy should, yearly, demand and draw in advance from the State Financial Department his former annual allowance of 400 rubles. In this way there appeared to be two Lomonosovs: one in Russia and the other in Germany. Schumacher also pocketed the allowances which should have been paid to the two other students until they returned to Russia."

Owing to his hot temper, Lomonosov's struggle against the German group often took on a very rough form, ending in violent quarrels and clashes with "assault and abuse." This fierce struggle led to Lomonosov's deten-

tion for six months. We may consider that Mikhail Vasilyevich Lomonosov's turbulent youth ended with his arrest.

However, it must not be thought that in the two and a half years after his return and up to his arrest Lomonosov let the struggle against foreigners keep him away from scientific work. He worked fruitfully not only before his arrest, but even when he was under arrest. At the Academy, as assistant professor, he taught chemistry, mineralogy, and versification; true, so far, he had only one student. At the same time he finished writing several important research works: *Elements of Mathematical Chemistry*, a thesis *On Infinitely Small Physical Particles Constituting Natural Substances*, and *The Elements of Metallurgy or Mining*; which was published only 20 years later. In all probability, at this time, too, his fundamental works—*The Origin of Heat and Cold* and *The Action of Chemical Solvents*—were mainly completed. They formed the essence of his lectures at the Academy in 1745. The ideas that Lomonosov put forward in these works, were entirely new, and left far behind the science of his day. They are reviewed in detail in the following chapter.

His talent as a poet developed and gained vigour.

When he was still in Freiberg Lomonosov wrote and sent to Petersburg an ode dedicated to the victory of Russian arms over the Turks and the taking of the fortress of Khotin. The language of the ode was rich and beautiful, and it immediately attracted general attention. And now, under detention, he wrote one of his best poems, *Evening Meditations*, that begins with the following inspiring lines:

The dying day conceals its face,
The fields are cloaked by misty night,
Dark shadows up the hill-tops pace,
The blood-red rays of sun take flight,
The myriad stars their greetings send,
They know no count, the sky no end.

In another remarkable poem, *Morning Meditations*, Lomonosov, with the perception of a genius, thus describes the activity of the sun:

If mortal man could soar on high,
To where the sun speeds in its flight,
There would unfold before his eye
A fiery and a wondrous sight:
For just as far as eye can see
A burning ocean surges free.
There breakers never reach a shore,
There through millenniums of time
Huge waves in ceaseless battles roar,
And flaming whirls sink and climb.
There liquid stones like water boil,
And countless blazing tongues upcoil.

When we now observe the sun with the help of up-to-date astronomic instruments, we are surprised to see how similar are our observations to the descriptions given by Lomonosov.

Lomonosov's successes as a poet added much to his popularity at the imperial court, thus greatly improving his position at the Academy. The line of conduct which Schumacher thought possible towards a Russian scientist was entirely impossible when it came to dealing with a poet well known at court.

Mention should be made here of something that happened in Lomonosov's private life in 1743. That year he received a letter his wife had written to Count Golovkin, the Russian Ambassador. She asked for information about her husband, from whom she had no word or money since his departure for Russia. Lomonosov wrote to her immediately, sending the money for her journey to Petersburg, and she joined him very shortly after that. Their son, Ivan, died in infancy.

After his wife's arrival Lomonosov's financial difficulties increased. He could not reconcile himself to the discrepancy between his knowledge and capacity and his

position at the Academy, and this caused him to suffer keenly. In 1745, when the court returned from Moscow to Petersburg, Lomonosov wrote a petition in which he said: "At the Academy of Sciences I translated into the Russian a number of books on physics and mechanics and some poetry from the Latin, German and French, and wrote a book in Russian on mining and another on rhetoric. Besides that, I taught students, carried out new chemical experiments and wrote new theses with all possible diligence. . . ." This was followed by a request to be appointed "Professor of Chemistry with a fitting salary, a position which will allow me, your humble servant, to serve my country through scientific research work and teaching the rising Russian generation."

Knowing Lomonosov's reputation at court, Schumacher dared not refuse, but still, on his instructions, the academicians resolved, "after a thorough consideration of the matter, and, having no doubt as to the candidate's knowledge and abilities, to oblige him, for greater clarity, to present to the board a specimen thesis on any subject, corresponding to the present level of science." Lomonosov soon presented the required thesis, and it was impossible for Schumacher to put any further obstacles in his way; on June 22 the board admitted that "the thesis presented by Lomonosov showed he deserved the rank of professor."

On July 25, 1745, Lomonosov was appointed professor of chemistry by a special *ukase*.

Of all the chairs at the Academy, the chair of chemistry was particularly unlucky from the beginning. Although capable scientists headed the other chairs at the Petersburg Academy in the eighteenth century, the chair of chemistry either had no leadership or was headed by people who never interested themselves in chemistry.

The first academician to be appointed to the chair of chemistry was a certain Bürger, a friend of Blumentrost.

who was then President of the Academy. When Blumentrost invited him to Petersburg he was aware that Bürger was not a chemist, but a physician, and he wrote: "If you find chemistry rather difficult—we can overlook that." Bürger's career at the Academy lasted no more than three months. He was fatally injured in 1726 when he drunkenly fell out of a carriage that was taking him home from Blumentrost's birthday party.

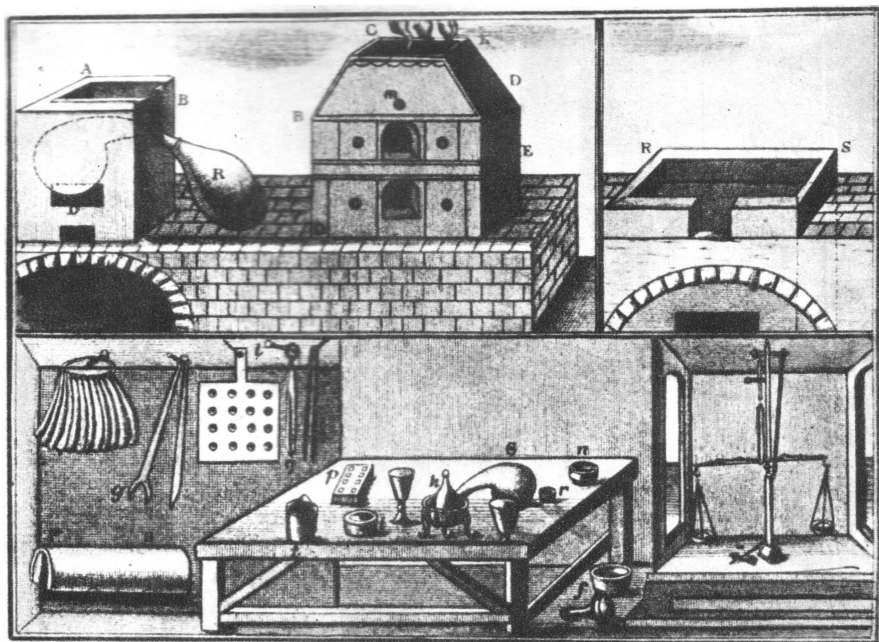
I. Gmelin, a naturalist specializing in botany, who was invited to occupy the vacancy, left on an expedition to Siberia soon after his arrival in Petersburg, returning only in 1743. At the Academy he concentrated his attention on the huge botanical collection he had brought back from Siberia, and disregarded chemistry.

The year's "activity" of Migend, the assistant professor of chemistry who succeeded Gmelin, and who was actually a physician, passed without leaving a trace in science.

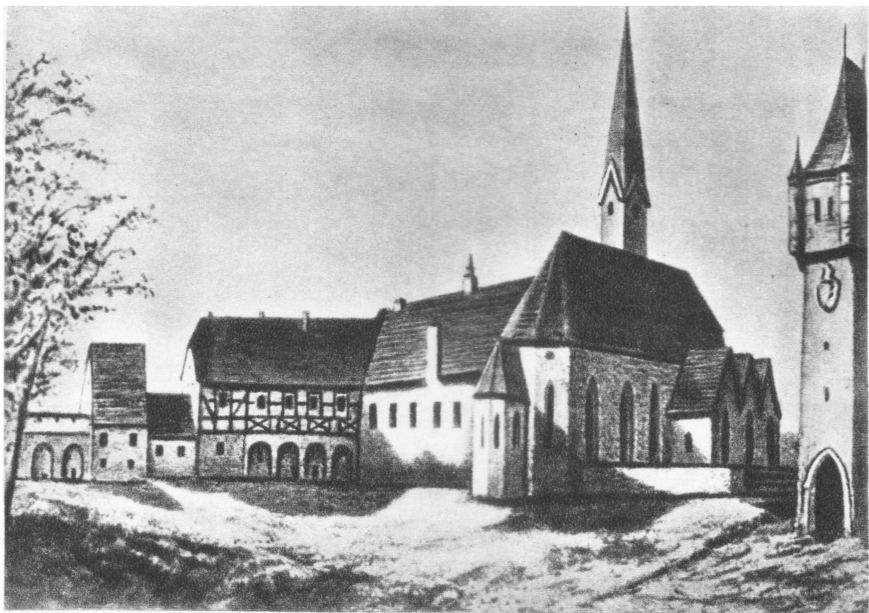
Therefore, we must with full grounds consider Lomonosov the first professor of chemistry at the Petersburg Academy of Sciences.

This appointment improved his material position, but his financial difficulties still caused him much anxiety. Nevertheless, he worked energetically and fruitfully on his theses and translated into the Russian the course in physics written by his teacher, Christian Wolf. This book, *Wolf's Experimental Physics*, played an important part in disseminating natural scientific knowledge in Russia.

The introduction that Lomonosov wrote to the book deserves special attention. In describing the progress of natural science in the seventeenth and eighteenth centuries, Lomonosov put forward the following vivid comparison: "After originating one geometric rule Pythagoras sacrificed one hundred bulls to Zeus. But if the skilled mathematicians of our time, who have originated new rules, were inclined to act in the same superstitious way,

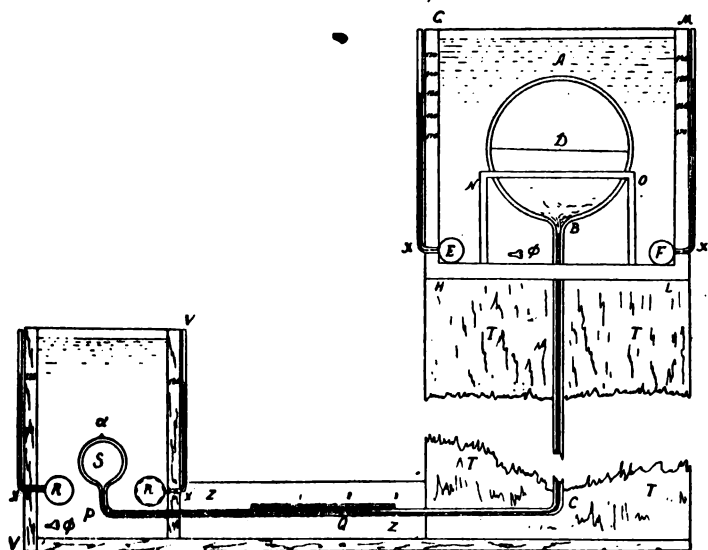


Lomonosov's chemical laboratory (18th century engraving)



Marburg University (engraving of the end of the 18th century)

I doubt if it were possible to find sufficient bulls and even cows, for that matter, in the whole world." Such progress became possible because "now scientists, especially those engaged in natural scientific research, rely little on the fantasy or empty prattle of individuals, but more on what



The drawing of Lomonosov's universal barometer

has been proved to be true. Physics—the principal branch of natural science—is now based exclusively on experiment.... Theories are arrived at after repeated experimentation." Thus did Lomonosov stress the importance of experimental work for the development of the exact sciences and the necessity of experimentally proving every scientific hypothesis.

When he was working on this translation Lomonosov discovered the poverty of the Russian scientific language

of his time. "I had to hunt up words to indicate certain physical instruments, actions, and objects. They may seem somewhat strange at first, but I hope that by usage, they will, with time, become more familiar." This made Lomonosov the founder of Russian scientific terminology. Our modern language contains numerous words which were first introduced by Lomonosov. Here are some of them: thermometer, formula, lens (burning-glass), piston, elasticity, spherical, atmosphere, barometer, manometer, ray-refraction, magnetic pole, etc. These words did not exist in the Russian language before Lomonosov.

The first edition of 600 copies of *Wolf's Experimental Physics* sold out so quickly that in less than a year, in January 1747, another 600 copies of the same edition were printed. Thirteen years later, in 1760, the second edition of *Wolf's Experimental Physics* appeared with addenda by Lomonosov. Some of these are interesting: the third addendum was written "to refute the existence of a special heat-producing matter," and in the sixth, *Electric Power*, he described an electric machine and his experiments with it.

Lomonosov's striving to spread education in Russia found expression in his public lectures on physics in the Russian language which the Senate permitted by a special *ukase*. The first lecture was given on June 20, 1746. Lomonosov prepared it very carefully and it was a great success. It was attended by Count Razumovsky, the newly-appointed President of the Academy, and many persons of influence at court.

The lectures were discontinued because of Razumovsky's departure, but that same year, on August 5, an advertisement appeared in the *Petersburg News* announcing that "those interested in experimental physics are informed that the public lectures of Mr. Lomonosov, professor at the Academy of Sciences, will be resumed from next Friday and delivered at the usual time, namely,

from three to five." It is not known how these lectures passed.

The success enjoyed at court by Lomonosov's poetry greatly influenced his general position in this period. Empress Elizabeth and her courtiers did not understand the importance of Lomonosov's scientific works, but they liked his rich odes. Especially successful was an ode written in 1747, the following inspiring lines of which have commanded the admiration of many generations since:

Oh, ye, whose birth on native soil
Our land so patiently awaits,
That her own sons might do the toil
Of masters come from foreign states.
Oh, may your days be ever blessed!
Oh, may your toil the land adorn,
And prove that Platos just as wise,
And Newtons of great enterprise
On Russian soil may be born.

Lomonosov's popularity at court helped him to realize his dream of building a chemical laboratory for scientific research work.

There had been chemical laboratories in Russia for a comparatively long time. At first the functions of chemical laboratories were carried out by chemists' shops, which first appeared in Russia in the reign of Ivan Grozny. By the time of Peter the Great there were eight chemists' shops in Moscow.

Peter was personally interested in chemical analysis and organized in Petersburg the first chemical research laboratory. In it ores were analyzed, and building materials, dyes and paints tested; it was therefore a laboratory of technical chemistry. Many of the observations made in the Petersburg laboratory as well as at the chemists' shops were of great scientific value. But these establishments did not aim at conducting experiments to prove scientific theories, or to verify scientific laws.

They were not research laboratories. And it was precisely the founding of a chemical research laboratory that Lomonosov petitioned for when he was still assistant professor.

In 1742 he sent his first petition to the Academy on the organization of a chemical laboratory but received no reply.

In 1743 he wrote again on the building of a chemical laboratory in which he "could carry on chemical experiments for the country's benefit." This time he received a reply but it stated briefly that his proposal had been "rejected for lack of funds."

But Lomonosov did not give up. In 1745 he sent a third petition, writing: "For the third time I am humbly requesting the Academy of Sciences for instructions to establish in a convenient place a chemical laboratory with the necessary instruments and materials."

In this petition Lomonosov pointed out that the laboratory was necessary not only for the advance of theoretical science, but also to help the development of the industry and the investigation of the natural resources of the country.

But this petition, too, led to nothing.

However, it was not the lack of funds alone that prevented the building of a laboratory. Lomonosov was an eyesore to the German group at the Academy, who, with the help of their leader, the all-powerful Schumacher, tried to hinder his work. This attitude was best expressed by Taubert, Schumacher's son-in-law, of whom it was said that he was "the heir to his property and position, and, in fact, would all but lead the Academy." He said: "Do we need ten Lomonosovs? Even one is a burden to us."

Lomonosov well knew the real reason for the delay in building a laboratory, and this made him even more dogged in getting his plan accepted. That same year,

1745, he decided to ignore the Academy and sent a substantiated suggestion for the building of a laboratory direct to the Senate. This petition was signed by eight professors.

Now things moved more quickly, and six months later the government issued an *ukase* on the building of a chemical laboratory "according to the enclosed plan."

But even after the government *ukase* had been signed, Schumacher managed to hold up the construction work for two years.

However, all obstacles were finally overcome.

On the morning of August 3, 1748, Lomonosov woke up with a feeling of joyful expectation. The event he had spent six years working for—the laying of the foundation-stone of the future chemical laboratory—was to take place that morning.

He dressed quickly, stepped out of the house and was immediately at the construction site—the laboratory was to be erected about forty paces from his house. There he found the building materials prepared and carefully arranged. He examined the site once more and then returned home for his breakfast. Soon the building contractor, Mikhail Gorbunov, came to him. He was a man of middle height, clever and honest. Together they went to the site. There they were joined by the other people who wished to be present at the ceremony.

The first stone of the foundation was laid in silence.

Thus began the construction of the first research chemical laboratory in Russia.

The work went on under Lomonosov's tireless supervision; he infected everyone with his energy, and the laboratory was completed in less than three months.

It was a one-storey brick house built on piles. The laboratory consisted of a vaulted hall and two adjoining "chambers," as Lomonosov called them.

The house had two chimneys, one for ventilation, the second as an outlet for products of combustion from the heating and many other laboratory ovens. One of the "chambers" served as an auditorium, where Lomonosov lectured to students and conducted his experiments. This room also contained chemical balance. The second "chamber" was used as a storeroom for chemical vessels and materials.

At the same time that the laboratory was being built Lomonosov energetically set about getting the necessary apparatus. In addition to chemical apparatus he equipped the laboratory with all the physical instruments in use at the time, saying that "a chemist without a knowledge of physics is like a man who has to fumble for everything in the dark." He attached much importance to balances, for "without determining weights and volumes," he said, "we cannot be certain there is no error in the phenomenon we wish to produce."

When Lomonosov started working in the laboratory, he wrote to the Academy asking for an assistant, as it was impossible for him to be always present; some of the experiments lasted for days. "The laboratory assistant," he said, "should have some experience in chemistry, and be able to take my place occasionally and to carry out my instructions."

I. Maneke, who received the appointment, was the first assistant at the chemical laboratory.

Thus appeared the first chemical research laboratory in Russia, founded through the energy and insistence of Mikhail Vasilyevich Lomonosov, the Russian scientist of genius.



CHAPTER II

The creative life of a scientist is an integral whole which, only conditionally, for the sake of convenience in reviewing it, may be divided into separate periods.

In Lomonosov's work there were three comparatively well-defined periods.

The first period dates from the time he completed his formal education and lasted till the building of the chemical laboratory, that is, till 1748, and was mainly devoted to theoretical investigation in physics.

The second period covered the time between 1748 and 1757. In these years Lomonosov was chiefly engaged in solving various problems of theoretical and experimental chemistry.

The third period lasted from 1757 to his death. During this last period Lomonosov, besides continuing his former activities, gave much of his time to various applied sciences, and to administrative work.

Lomonosov attached great importance to his investigations in physics. "Poetry is my pleasure, physics—my exercise," he would say. He wrote several fundamental works on physics in the years before the appearance of the laboratory, but their significance was understood only much later. It is quite natural, therefore, to stop for a brief discussion of the content and the scientific importance of his main works of that period. These works include three

theses: *On Infinitely Small Physical Particles Constituting Natural Substances, The Origin of Heat and Cold* and *An Essay on the Theory of the Elastic Force of Air*.

About two thousand five hundred years ago man first arrived at the brilliant thought that all matter in the universe is made up of minute invisible particles. This idea was expressed in its most perfect form by Democritus, the remarkable Greek philosopher. He considered these minute particles, of which everything in the world is formed, to be indivisible and named them "atoms" ("atom" in Greek means "indivisible"). "We usually speak about things as being sweet or bitter, warm or cold, about colour and smell," he wrote, "but in reality, there exist only atoms and empty space."

This idea explained many phenomena of everyday life. For example, the scent of flowers was explained thus: atoms, flying out of the bell of a flower, get into the nose and call forth the sensation of smell. In a similar way was explained man's capacity to see objects around him, and so forth.

Democritus' views were very widespread in ancient times. But centuries passed and the situation changed.

The Christian Church, which acquired enormous power in the Middle Ages, tried to turn human thought away from rational and material things. It could not accept the idea that the world, after all, consists of nothing more than material particles—the atoms of Democritus. Democritus' views were declared pagan. In its struggle against the atomic doctrine the church was supported by the temporal powers. On September 4, 1626, the Paris Parliament issued a special decree forbidding the propagation of atomic ideas on pain of death.

But the development of science cannot be stopped by issuing decrees, however threatening they may be. Some decades later it was precisely in Paris that the idea of

the atomic structure of matter was revived. This time it was expressed by the French philosopher Pierre Gassendi.

He was supported by Robert Boyle, the famous English natural philosopher (1627-1691).

It should be borne in mind, however, that the atomic ideas of even the greatest scientists of that time were imperfect and inconsistent, as can be seen from the fact that, though they recognized material atoms, they still admitted the existence of imponderable, immaterial substances.

Together with atomic ideas, opposing views were very widespread among the scientists of that time. Some scientists maintained that substance can be divided infinitely, and denied the existence of minute indivisible particles—atoms or corpuscles. At the time of Pierre Gassendi this outlook was propagated by René Descartes, one of the greatest of French philosophers.

Nor did such prominent scientists as Gottfried Leibnitz (1646-1716) and his follower Christian Wolf recognize the theory of material atoms.

It is therefore all the more remarkable that Lomonosov should appear as a consistent atomist, in contrast to his teacher, even in his first compositions.

In two of his theses: *On Infinitely Small Physical Particles*, which he presented to the Academy in 1743, and the earlier *Elements of Mathematical Chemistry*, Lomonosov asserted that all matter was made up of minute material particles, which he called "elements" and "corpuscles." By "corpuscles" he meant compound particles, consisting of simple particles—"elements." Now, instead of "corpuscle" we use the word molecule and instead of "element"—atom. It is remarkable that the difference between the molecule and the atom, made clear by Lomonosov, was precisely formulated for the second time at a special international congress of chemists only a hundred years later.

Lomonosov considered that such properties of substances as colour, smell, specific gravity, etc., are determined by the properties and the type of minute particles, and by their reciprocal arrangement and movement, and since "corpuscles" and "elements" represent infinitely small bodies, possessing all the properties of an ordinary body, their motion and interaction follow the general laws of mechanics. That is the reason why Lomonosov concluded that "inherent properties of any minute body can be explained by the laws of mechanics." And as mechanics, in its turn, widely applies mathematical methods, Lomonosov set himself a very unusual problem for his time—that of creating "mathematical chemistry." The solution of such a problem would have turned chemistry from a science depending on skill into a precise science. It is regrettable that the above-mentioned theses belong to those few of his works that he did not publish. They would undoubtedly have attracted attention and possibly greatly influenced the further development of science. A long time passed before the appearance of theses in which atomic ideas were as consistently developed as in the works of Lomonosov. The above-mentioned theses formed part of a big work which he planned to devote to the atomic theory, or, as he expressed it, to "corpuscular philosophy."

Here, naturally, arises the question why Lomonosov did not publish these compositions. A certain light is thrown on this question by some of his letters.

From a letter to a friend, L. Euler, a member of the Petersburg Academy of Sciences and a highly gifted mathematician, we can see how exacting Lomonosov was to himself. He wrote: "I could, certainly, publish the whole system of corpuscular philosophy, but I am afraid it would look as though I were presenting to the world of science the unripe fruit of a precocious mind if I expressed many new views which, for the most part, are quite contrary to the views of our great scientists." He also feared

"to grieve and bitterly disappoint the last years" of his teacher, Christian Wolf, whose doctrine would have thus been fundamentally nullified through Lomonosov's argument.

Lomonosov published only parts of these two theses, which he elaborated to perfection.

The nature of heat was an important problem of natural science at that time. The development of the industry and the numerous attempts to build a steam-engine made many scientists in different countries turn their attention to this problem. How did science then solve the problem?

There was in those days a general method which European scientists used for solving difficult questions. To explain incomprehensible and puzzling problems, science had at its disposal a whole set of mysterious imponderable substances or "matters." For example, scientists spoke of an "imponderable thermal substance" or "thermal matter," an "imponderable matter of elasticity," a "matter of cold," a "matter of attraction," etc. With these "matters" they could verbally explain anything they wished.

If one was interested why water in a kettle became heated when put on the fire, one would get a ready answer: the imponderable thermal matter or heat fluid produced by the fire entered the water and heated it.

In the same way, the resistance of gas to the reduction of its volume was explained by the "imponderable matter of elasticity" contained by gas which conditioned its elasticity.

The "explanations" of natural phenomena by means of imponderable matter remind us of certain reasonings of the hero of one of Molière's comedies.

Poppy seeds contain a chemical substance called opium which plunges a person into deep sleep. In the comedy the satirized ignoramus, who fancied himself a scientist, explained the narcotic property of opium by

stating that "opium narcotizes because it possesses narcotic properties."

Such explanations, of course, do not help us to understand why and how various phenomena take place in nature.

However, the existence of "thermal matter" was recognized by nearly all the greatest scientists of Lomonosov's time. And among them by Wolf, whom Lomonosov deeply respected.

The idea of "imponderable thermal matter" was organically alien to Lomonosov's materialistic corpuscular philosophy. His consistent struggle against it runs like a red thread through all his creative work in science.

In January 1745 Lomonosov read his thesis, *Meditations on the Origin of Heat and Cold*, at two sessions of the Academy of Sciences. In this work Lomonosov convincingly showed that the origin of heat can be explained without resorting to the existence of a special "heat fluid."

"It is a well-known fact," declare the opening words of his thesis, "that heat is produced by motion: reciprocal friction causes hands to get warm and wood to catch fire; by striking flint against steel we produce sparks; through frequent hammering iron becomes red-hot, but when the hammering is stopped the heat decreases and dies out."

But "bodies can move in two ways—total motion, when the whole body uninterruptedly changes its place with the particles remaining immovable in relation to each other and internal motion, which is the movement of the infinitely small particles of the body."

Which of these movements produces heat?

Lomonosov came to the conclusion that "in so far as the most intensive total motion often does not produce any heat and great heat may be observed when there is no such motion, we can say that heat is caused by the internal motion of matter."

Heat is thus the motion of minute particles, of the corpuscles we have already mentioned. The higher the temperature, the faster the motion of the particles. But does not this reasoning contradict common experience? For motion is invisible in heated substances, and cannot be revealed even by the microscope. Lomonosov foresaw this objection, and he wrote: "The existence of motion cannot be denied where it is not seen: who, indeed, will deny that when a strong wind blows through a woods the leaves and branches move, even though from a distance this movement cannot be noticed. As in the case of distance, the smallness of the particles, too, makes the motion of matter in hot substances invisible to the eye."

Further Lomonosov discussed the question of the type of motion that should be connected with heat and, from the viewpoint of the science of his time, logically showed that heat is connected with the rotatory motion of particles. At present we know that the thermal motion of particles may be both rotatory and translatory, or oscillatory.

Through argument, based upon experiments, Lomonosov demonstrated that "heat cannot be explained by an accumulation of some fine matter specially intended for this purpose." The revolutionary character of Lomonosov's explanation cannot be overestimated. Almost a hundred and fifty years later Frederick Engels, the great founder of dialectical natural science, wrote: "The discovery that heat is a molecular motion was epoch-making."

It must be noted that the idea about an "imponderable matter of heat" or "thermal matter," as it was called, was deeply rooted. For example, when, towards the close of the eighteenth century, Antoine Lavoisier, the well-known French chemist, composed a list of chemical elements (elementary substances), he headed the list with two imponderable matters—light and heat.

This idea about an "imponderable thermal matter" existed in science up to the middle of the nineteenth century. It was only in the latter half of the last century that, under the pressure of an increasing number of facts disproving the existence of heat fluid, scientists arrived at the same conclusion that Lomonosov had distinctly formulated one hundred years earlier.

Lomonosov drew two remarkable conclusions in his thesis. In paragraph 26 he wrote: "It is impossible to name any definite rate of movement without imagining a still greater one." Consequently, the temperature of a substance may be very high. And, indeed, we now know that inside stars the temperature reaches millions of degrees.

"Conversely," Lomonosov added, "the same movement may be reduced to such a degree that the substance becomes motionless—and a further reduction of movement is impossible. Consequently, there must exist a lowest and absolute temperature of cold." This conclusion coincides with the latest notions, according to which the random molecular thermal motion must cease at absolute zero, or 273.2° C. below the usual zero.

Paragraph 25 of the thesis is extremely interesting. It begins with the assertion that "A body *A* when acting on another body *B* cannot impart to the latter a greater rate of movement than that which it itself possesses." From this Lomonosov drew the conclusion that "a cold body *B*, when plunged into another body *A*, is unable to attain a higher temperature than that possessed by body *A*." This is one of the most important laws of present-day natural science.

Several years after he wrote his *Meditations on the Origin of Heat and Cold*, which banished the "thermal matter" from science, Lomonosov, with similar resolution, made short work of another "imponderable matter"—the "matter of elasticity."

In 1748 he submitted to the Academy of Sciences a thesis entitled *An Essay on the Theory of the Elastic Force of Air*, in which he developed the ideas contained in his early works.

"In our endeavour to find out the cause of the elasticity of air, we consider it superfluous to turn for help to that peculiar floating fluid to which so many scientists—as is the custom of this age, so abundant in fine matter—generally resort, in order to explain natural phenomena. We are content with the fine and mobile character of the air, and look for the cause of elasticity in its own matter."

What, then, evokes the elastic force of air?

Lomonosov was confident that "it is produced by some direct interaction of the atoms" of the air.

"Evidently," he wrote, "flying at random, separate atoms of the air collide when they approach each other... the next atoms mutually spring away, strike those nearest to them and again spring away; constantly repulsing each other by reciprocal shocks they strive, in this manner, to disperse in all directions." And it is namely these countless collisions of gas-atoms which, added together, create the force we encounter when we try to compress gas.

Through convincing argument Lomonosov showed that the elasticity of gas may be explained by the movement of the particles of gas without resorting to any "imponderable matter."

He furnished this *Theory of the Elastic Force of Air* with a very interesting addendum.

In his opinion, particles making up gases are incompressible corpuscles of small but definite volume. When the volume of gas is reduced, only the intervals between the separate particles decrease, and this is the reason why gas can be compressed with comparative ease. However, if the volume of gas is reduced further, then, as Lomonosov indicated, the space free from gas-particles will form only a small portion of the whole

volume. The greater part of the gaseous volume will be occupied by incompressible particles.

Under these conditions gas will offer more resistance to further compression than uncompressed gas.

This fact, first noted by Lomonosov, was "discovered" a second time 115 years later by Athanas Dupré, a French scientist.

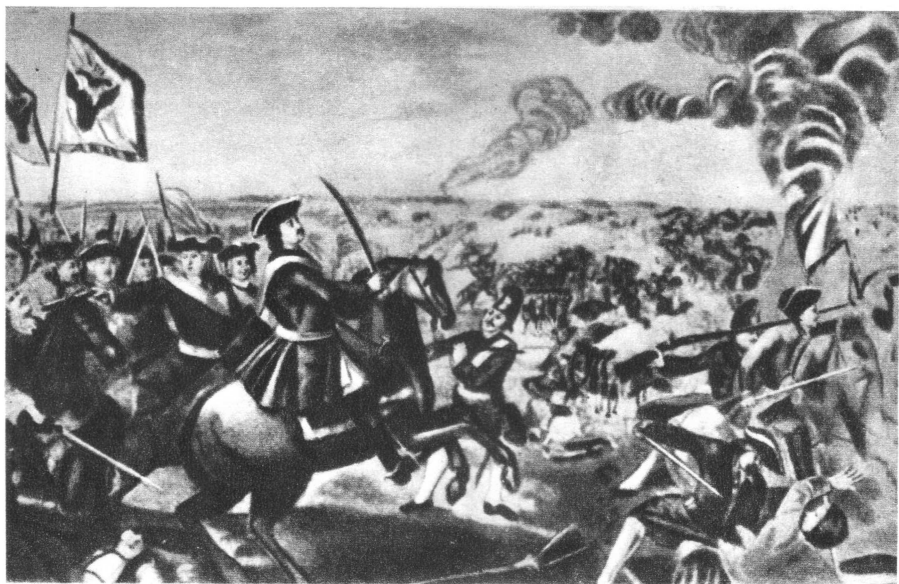
The theses setting forth the mechanical theory of heat and a new explanation of the elasticity of gas were published in Latin in the journal of the Petersburg Academy of Sciences. This journal was subscribed to by all foreign academies, universities, and scientific societies, and in this way Lomonosov's works became widely known in Europe. His *Meditations on the Origin of Heat and Cold* called forth animated discussion. The overwhelming majority of scientists in Europe did not understand Lomonosov. His views were too revolutionary. Many journals published articles containing the most ignorant and prejudiced criticism of his works, irritating him greatly. His patience gave way in the case of J. Arnold, whom history has deservedly forgotten. That enterprising magister decided to receive his doctor's degree at Erlangen University in Germany by publicly "refuting" Lomonosov's theory. A summary of Arnold's report, written in a most impertinent tone, was published in a German newspaper, which, ludicrously enough, was called *The Impartial Hamburg Correspondent*.

Indignant at this unscrupulous criticism, which entirely distorted his theory, Lomonosov decided to give Arnold and his supporters the answer they deserved.

In his rejoinder to Arnold's criticism, sent to Euler, the Petersburg academician, he wrote: "The publisher of the newspaper . . . was guided more by ill-will than by love of science when he attacked the works to which I had given such tireless energy and care and, without having understood my theory, showered abuse on it. I



Peter I. Mosaic portrait by Lomonosov



Battle of Poltava. Mosaic picture by Lomonosov

am sending you the most obvious proof of his malice and stupidity."

Euler replied with a friendly letter. "I am well familiar with the unscrupulousness and style of German newspapermen," he wrote, "and they do not affect me in the least. It makes me laugh when I see them tearing to pieces and trying to distort the finest works. . . . I always hold that such articles should be treated with contempt. . . . Everybody knows that none of the essays on the origin of heat that have appeared so far fully explain this subject. . . . We can only be grateful to you for what you have done towards dispelling the obscurity which had clouded the problem. . . . I gave your report to Professor Formey, who has promised to publish your protest in a French journal."

In one of his letters to Petersburg Euler praised Lomonosov's works. "Lomonosov's thesis on the origin of heat," he wrote, "is something quite different. All we have hitherto heard from others on the matter is absurd and groundless and, therefore, far from being a trustworthy explanation; the objections of his opponents prove on the one hand that they misunderstood his idea, and on the other expose their own profound ignorance. . . ."

Formey fulfilled his promise and published Lomonosov's protest. In a letter enclosed with the proofs of Lomonosov's article Formey said: "I am sending you herewith the page-proofs of the journal in which the thesis is being published. I saw it as my duty to defend your just cause against such slanderers."

Professor Euler appraised Lomonosov's works on physics in an official report to the Academy in the following words: "All these theses are not only good, they are superb, for he writes on very important physical and chemical problems, which up to this day the greatest minds had been unable to understand or explain. . . . I must do justice to Mr. Lomonosov and say that he has a great

talent for explaining physical and chemical phenomena. It is desirable that other Academies should be able to produce discoveries equal to those of Mr. Lomonosov's."

We have given a detailed account of the references published abroad on Lomonosov's physical investigations in order to refute the widespread and, to our mind, unfair opinion that Lomonosov's works were unknown in foreign countries and, therefore, did not influence the development of science in Europe.

Lomonosov's work was not continued by scientists abroad because it was a hundred years in advance of the science of his day, and not because it was unknown.

Time is the best judge of all scientific theories. The correctness of the remarkable ideas, first expressed by Mikhail Vasilyevich Lomonosov, the gifted Russian scientist, has been proved by the development of physics in the course of nearly two hundred years that have passed since his age.

In the years following the building of the chemical laboratory, Lomonosov's already wide range of activities became still wider. The realization of this cherished dream seemed to fire him to even greater effort. Besides research work in physics, he carried on many investigations in chemistry and chemical technology. And it was in these years that Lomonosov first showed himself as playwright and painter.

Time has shown that of all his different activities in this period the most important were his investigations in physics and chemistry.

After the laboratory he had wanted so much was built and equipped, Lomonosov gave it all the time he could. The minutes of the Academy meetings of the time usually contained a note, stating that "Counsellor Lomonosov begs his absence to be excused as he has to attend to important work in chemistry."

His capacity for work was as great as ever. When, towards the end of his life, he drew up a list of his "compositions and other work," Lomonosov wrote that in those years, in addition to other activity, he had conducted over 4,000 experiments on the production of glass during which he not only composed the recipes, but also weighed out most of the materials and placed them in the oven.

His style of work in the laboratory was characterized by a great industriousness and personal participation in the conduct of experiments. Characteristic also is the fact that he began his work in the new laboratory by concentrating on the solution of an important practical problem—the elaboration of a new process of chemical technology.

Lomonosov belonged to the type of scientist whose theoretic investigations harmoniously combine with the solution of important practical problems. On the 225th anniversary of his birth the newspaper *Pravda* wrote: "For him science was directly connected with practice and experience, with the industrial exploitation of the country's natural resources and with the development of her productive forces and culture."

At the same time Lomonosov tried to utilize all his practical investigations for the development of theoretical science. "During my practical experiments," he wrote, "I always register the circumstances which refer to chemical theory."

Some years before the laboratory was built Lomonosov saw some pieces of Italian mosaic work, and their beauty so captivated him that he decided to organize the production of mosaic pictures in Russia. He worked to solve this task in his new laboratory. And, as usual, he approached the problem in his own way. Instead of coloured stones, as used for mosaics in Italy, Lomonosov decided to employ specially prepared stained glass.

During the elaboration of methods of producing such glass, physico-chemical problems interwove with purely artistic tasks—the obtaining of the necessary shades used in painting. Such a complicated problem pleased Lomonosov. He was also eager to prove that “chemical investigations are highly necessary and useful for the development of art.”

For this reason he put his heart into this work and soon achieved such perfection in producing and polishing stained glass that already in 1752 he made a large mosaic picture. This success inspired him to further effort. Seeing that the laboratory was unsuitable for the mass production of stained glass, he insistently began to petition for the organization of a special factory where stained-glass decorations and stained-glass articles such as beads, bugles, etc., could be produced. His exceptional energy helped him to get a site at Ust-Ruditsi, 64 *versts* from Petersburg, for the building of such a factory.

He personally designed all the necessary machinery and directed their construction, and soon had the factory in operation. It played a big role in promoting the production of mosaic pictures. In 1756, as a mark of gratitude for establishing the factory, Lomonosov presented the Senate with a mosaic portrait of Peter the Great; he made the portrait himself. But the scientist of genius proved to be a poor businessman. The financial condition of the factory gave him much trouble.

In 1761 he received an order from the government to decorate with mosaic pictures the mausoleum for Peter the Great that it intended to build. With the money given to him for this purpose he built a special workshop near his house and set to work with his pupils and assistants.

Mosaic pictures were made in the following way: first elongated pieces of glass of various colours were made and polished at one end; then these pieces were used to make a picture in a copper tray which served as

the foundation. A painting, prepared in advance, was used as a model. The coloured pieces of glass were fastened to the copper tray by special cement and the picture put together in this manner was given a polish.

Lomonosov's workshop produced, among others, a picture portraying the Battle of Poltava, in which Russian troops defeated the troops of Charles XII, King of Sweden.

The *Battle of Poltava* is today in the old building of the Academy of Sciences in Leningrad, and even now the brilliance of its colours is enough to take one's breath away.

The model for the picture was painted by Lomonosov and, when admiring the *Battle of Poltava*, we cannot but be struck by the greatness of his talent as an artist.

The size of the picture is amazing. It is 28 feet wide and nearly 26 feet high. The copper tray together with the fastening weighs more than two tons.

The picture was finished in the second half of 1764, shortly before Lomonosov's death. Soon after his death the stained-glass factory at Ust-Ruditsi and the workshop in Petersburg were closed. Altogether the workshop produced 43 pictures, 22 of which have not been found.

While he experimented on the production of stained glass and porcelain, Lomonosov did not neglect his purely chemical research work. It was precisely in this period that Lomonosov experimentally verified the fundamental law of nature he had established some time earlier, and created an entirely new science—physical chemistry.

It is necessary to mention the state of chemistry at that time before proceeding to a description of this aspect of Lomonosov's activities. Chemistry, as a science, was non-existent. This word was used to denote the art of decomposing compound substances into simpler bodies and conversely—to create compound substances out of simple ones. But in these processes neither the weight of

the original substances nor that of the products obtained during these chemical operations was taken into consideration. No wonder then that, depending on the "art" of the chemist, different products were obtained during the decomposition of the same substance. The lack of any notion about pure chemical substances was also one of the main reasons that led to contradictory results. The names that were given to chemical substances in those days usually signified more or less arbitrary mixtures of various products. That was why the same experiments conducted by different chemists often gave different results. The most fantastic explanations were given to interpret the chemical conversions thus produced. The honour of converting chemistry from an "art" into an exact science belongs to Lomonosov.

"True, many scientists deny the possibility of basing chemistry on the laws of mechanics and of making it an exact science," Lomonosov wrote in his first thesis on chemistry, *Elements of Mathematical Chemistry*. "But," he added, "these are people who have lost their way in the darkness of latent properties." Meanwhile, chemistry is "a science of the changes taking place in a compound substance, for the very reason that it is composed of several substances." Further, Lomonosov said: "Since in science it is the accepted thing to prove every statement, then in chemistry, too, everything said must be proved." These definitions coincide with our modern views.

It was characteristic of Lomonosov that he connected his notions about chemistry with the atomic theory he had developed. He firmly believed that to understand chemical changes it was necessary to study the properties of the minute particles that compose all substances.

Using the atomic theory he formulated the idea of an elementary chemical substance or a chemical element. This idea was most important for chemistry. As already

mentioned, all bodies, in his opinion, consist of minute particles ("elements"). When they link, these minute particles form larger particles—corpuscles or molecules, as they are called today. "Corpuscles are homogeneous if they consist of the same number and kind of particles (elements) joined in the same way."

Lomonosov called a substance consisting of homogeneous corpuscles the "origin." The "origin," which cannot be further decomposed, coincides with the chemical "element" of modern chemistry.

According to Lomonosov "a compound substance (*or a chemical compound, as it is called now*) is one that consists of two or several different elements which are linked in such a way that the ratio of the parts of the elements in each separate corpuscle is the same as in the whole compound substance." There can be no doubt that if Lomonosov had published these lucid definitions of his fundamental ideas on chemistry, they would have greatly influenced the development of chemistry and there would have been no need to formulate them again a hundred years later.*

Lomonosov clearly understood that in order to be sure of the results of chemical experiments it was necessary to work with pure chemical substances. When he drew up a plan of chemical research work in his laboratory, he wrote: "1) The natural substances that are to be employed in a chemical experiment should first be

* The works of Soviet scientists moved scientists abroad to recognize Lomonosov's services. A text-book on chemistry (published in 1947) compiled by L. Pauling, a well-known American chemist, points out the role Lomonosov played in developing ideas on the structure of substances and the division of chemical substances into elements and combinations.

Another American text-book on chemistry, compiled in 1946, contains a literal rendition of Lomonosov's definition of a chemical combination. This definition is called Lomonosov's Law.

properly cleansed from any foreign matter, which may lead to error as the experiment progresses. 2) The cleansed substances must be decomposed as far as possible into the elements from which they are naturally formed. 3) To clearly prove that decomposed substances really consist of the elements obtained, they should be synthesized again and again." The realization of this programme alone would have brought chemistry considerably closer to an exact science, but Lomonosov formulated with similar lucidity the last and most important condition that must be fulfilled during chemical experiments in order that a given experiment, conducted by different chemists, should produce the same results.

"Anyone desiring to conduct physico-chemical experiments," he wrote, "must make use of . . . weights and volumes." That is why in the plan, a part of which we cited above, Lomonosov wrote: "In all such experiments I shall observe and register not only the actions, weights and volumes of the substances and vessels employed, but also all the accompanying phenomena that may become manifest."

All these ideas came to Lomonosov through his consciousness of the close relationship of chemistry with physics (and through the latter, with mathematics). This connection was best of all explained by Lomonosov in his famous *Report on the Usefulness of Chemistry Made on September 6, 1751*.

"Eyes are useless to a person who wants to see the inside of a thing, but has no hands to open it. Hands are useless to a person who has no eyes to see the inside of a thing even when it is open. Chemistry may justifiably be called the hands of physics, and mathematics—its eyes. And though one requires the other's help in order to investigate the internal properties of substances, they, at the same time, often lead men's minds along various paths. The chemist, seeing that every experiment can give

different and often quite unexpected results, hopes to make the quickest use of it and looks upon the mathematician's reflections over exercises with points and lines as upon futile efforts, and laughs at him. The mathematician, on the other hand, who is quite certain of his statements for he can clearly prove them by demonstration, and can deduce the unknown quantity or a property through indisputable and continuous calculation, scorns the chemist, whom he considers to be a man limited by practice and lost in a maze of disorderly experiments; besides this, the mathematician, being accustomed to a clean sheet of paper and light geometrical instruments, has an aversion to chemical smoke and ashes. And, therefore, chemistry and mathematics, these two sisters, whose purpose is the same, have mostly given birth to sons of different thought, because the perfected science of chemistry has not yet been connected with a profound knowledge of mathematics. . . ."

In developing further the idea of the relationship between physics and chemistry Lomonosov, in 1752, created the new science of physical chemistry, which we have already mentioned.

He precisely defined the problems of physical chemistry: "Physical chemistry is a science which explains on the grounds of physical experiments and laws the processes taking place in compound substances under chemical reactions. It may be called chemical philosophy."

His *Course of Genuine Physical Chemistry* amazes the reader by the profundity of the ideas it contains. By establishing the science of physical chemistry he outstripped the science of his day by more than a century. It was only in 1865 that Professor Beketov, the Russian chemist, introduced the world's first course of physical chemistry at Kharkov University.

In 1752-1754 Lomonosov lectured on physical chemistry

to the students of the university at the Academy. These lectures were conducted on exactly the same pattern in force today: they were accompanied by practical work carried out by students themselves, for, Lomonosov said, "a chemist must draw his knowledge of this science not only from books, but also from a diligent application in practice of his own skill."

Lomonosov constructed numerous apparatus of his own design for practical work in physical chemistry. In a perfected form some of these apparatus are still in use.

For practical work in physical chemistry Lomonosov intended "to add to purely chemical experiments ... experiments in optics, magnetism and electricity, for," as he explained, "I have found out not only from the practice of other authors, but also from my own experience, that chemical experiments combined with physical experiments produce remarkable results."

We have, therefore, full right to consider Lomonosov the founder of physical chemistry.

In 1753 Lomonosov started a series of experiments, which were of great importance not only for chemistry but also for natural science in general. In order to appreciate better the importance of these experiments, let us briefly examine some problems of chemistry in Lomonosov's day.

At that time chemists in different countries were interested in the changes taking place in bodies during the processes of burning or annealing. The difference in the behaviour of various bodies during these processes allowed scientists to divide all bodies into three categories. When they were consumed by flame, bodies of the first category, wood or coal for example, left a certain quantity of incombustible ash. Bodies of the second category did not burn, but when annealed they changed their appearance. For example, solid and shining metals changed into brittle and earthy scale when burned. And lastly,

bodies of the third category, such as stones, did not change at all when annealed.

This difference in the conduct of bodies when subjected to burning was explained by eighteenth-century scientists from the standpoint of a unified theory. And, indeed, would it not be natural to surmise that all bodies consist of the original substance of the given body and a certain substance common for all—the “matter of combustibility” which disappears when the body is burned? If a body can burn, or, in general, change during burning, it means that the body contains combustible matter, but if the body remains unchanged, it means that this matter is absent. The matter of combustibility was named “phlogiston.”

The whole of eighteenth-century chemistry may be called “the age of phlogiston.” The phlogiston hypothesis helped scientists to unify for the first time a great quantity of separate facts, which made up the content of the chemistry of that period. It was considered that annealing isolated phlogiston from metal, and there remained an earthy residue—scale. This scale, when combined with phlogiston, again produced shining metal. It was quite natural that there should arise a question as to the quantity of phlogiston contained in various metals. This could be discovered by experimentation. It was only necessary first to weigh the metal, then to anneal it and to weigh the scale. The difference in weight would give the weight of phlogiston. Such an experiment was made by Robert Boyle, the English natural philosopher, before the phlogiston hypothesis appeared.

Boyle placed a weighed piece of lead in a glass retort, carefully sealed the opening and then heated it over a fire. After two hours’ annealing the lead became partly changed into scale. On opening the retort and weighing the remaining lead and scale, Boyle noted down that his observation showed a weight increase of six grains. It was

difficult to explain this unexpected result with the help of the phlogiston theory; phlogiston was supposed to leave the body during annealing, but the scale that remained proved heavier than the original metal. It had to be admitted that a substance became lighter when phlogiston combined with it. Boyle suggested another explanation of his experiments. In his opinion the "matter of fire" penetrated the glass walls of the retort and, uniting with the metal, formed the scale which was heavier than metal.

Lomonosov, who opposed various "fine matter" on principle, doubted Boyle's explanation. He had proved that heat is the internal movement of a substance, and could not accept the mysterious "matter of fire."

Lomonosov attentively read Boyle's papers and soon found the latter's mistake. In describing his experiment Boyle wrote that after two hours' annealing the sealed end of the retort was opened and a stream of outer air noisily rushed in. Lomonosov correctly concluded that the air that had rushed into the retort had caused the unexpected result.

"Boyle's experiments on the increase of weight under the action of fire," he declared in a report to the Academy of Sciences in 1745, "show only that it was either parts of flame burning the body, or parts of the air passing over the annealed substance that possess weight." Later he stated already with confidence that "there is no doubt whatever that the particles of air which flow incessantly over the annealed body combine with the substance and increase its weight."

There was also another, more important reason that impelled Lomonosov to verify Boyle's experiments. Already in 1748 he had established a very important law of nature. In a letter to Euler on July 5, 1748, Lomonosov wrote: "All the changes occurring in nature follow the law that what is lost by one body is gained by another.

For example, the loss of matter in one place is compensated in another. The hours spent on night watch will reduce by the same number the hours of sleep. This universal law of nature also extends to the law of motion: for a body that moves by its force another body will itself lose as much force as it communicates to the one it moves."

Lomonosov had applied this law already in 1744, when he wished to explain why water cools when salts are dissolved in it. He wrote: "When one body accelerates the motion of another body, it communicates a part of its motion to that body, but in so doing, it loses exactly the same quantity of its own motion. Therefore, the particles of water, when accelerating the rotatory motion of the particles of salt (*during the processes of their dissolution*), lose a part of their own rotatory motion. And as this motion is the origin of heat, it is no wonder that water cools when salt is dissolved in it."

However, "science relies but little on the fantasy of individuals," and while the above-mentioned observation of the dissolution of salt tallied with half of the law—the constancy of motion—Boyle's experiments seemed to refute the other half, the constancy of matter.

Lomonosov was positive that there was no "matter of fire." He had to verify Boyle's experiments.

The establishment of the laboratory made it possible for him to prove by experiment that he was right, and in 1756, speaking at a conference of the Academy of Sciences, Lomonosov said: "I experimented with metals in hermetically sealed glass vessels to see whether simple heating increased their weight. These experiments showed that Robert Boyle, of whom I think highly, was wrong, for the weight of the burnt metal remains unchanged when the outer air is excluded." The increase of the weight of the scale was explained by the fact that air combined with

the metal in the retort. Thus was confirmed the fundamental law of nature that Lomonosov had discovered!

Lomonosov's law was a milestone in the development of science and, therefore, let us stop to consider, in brief, its importance.

The idea that either matter or motion taken separately can never be destroyed was formulated as a conjecture already before Lomonosov.

Lomonosov's service lay in the fact that, having the gift of foresight inherent in genius, he unified "all the changes occurring in nature" under one universal law, that he proved and confirmed by experiment."

The "matter" of whose preservation Lomonosov speaks in his law is close to the philosophic definition of matter given by Lenin, who said that "matter is a philosophical category denoting the objective reality which is given to man by his sensations, and which is copied, photographed and reflected by our sensations, while existing independently of them."

The experiments proving the constancy of the mass during the annealing of metal demonstrated only one concrete form of the universal law of nature, the law of the preservation of matter and motion discovered by Lomonosov.

Only now, two hundred years after Lomonosov, can we understand and appreciate the importance of this great generalization. For the last century Lomonosov's law not only served as a foundation for the development of natural science, but also ensured the tremendous technical progress witnessed by us.

Seventeen years after Lomonosov completed his experiments they were repeated by Antoine Lavoisier, the French chemist. His results fully coincided with the results obtained by Lomonosov. In 1789 Lavoisier published his well-known *Elementary Text-Book on Chemistry* where, in the chapter "Fermentation of Wine," he followed Lomo-

nosov's law when he spoke of the preservation of the mass during chemical conversion.

It cannot be decided now with full certainty whether Lavoisier was aware of Lomonosov's works mentioned above. Probably he was, because, besides the letter to Euler, Lomonosov informed the Academy in 1760 of the law he had discovered, and published it in his *Thesis on Solidity and Fluidity*. Unquestionably, Lavoisier read Lomonosov's *Meditations on the Origin of Heat and Cold* in which the latter clearly pointed out the mistake in Boyle's experiments. This is indicated by the circumstance that in one of his works Lavoisier mentions an article written by Academician Riechman printed in the same volume of *New Commentaries of the Petersburg Academy of Sciences* in which were published four of Lomonosov's theses, including his *Meditations on the Origin of Heat and Cold*. We cannot imagine that with the volume in his hands Lavoisier did not read Lomonosov's works. Personally, Lavoisier never credited himself with the discovery of this law.

In 1842, a hundred years after Lomonosov, R. Mayer, a German doctor, formulated the famous law which later became known as "the law of the preservation of energy." Now we know that this law is also only one of the concrete formulations of the general principle discovered by Lomonosov.

In maintaining the constancy of the quantity of energy, Mayer did not connect it with the principle of the preservation of the mass, so widely known at that time. Thus "outstripping Lavoisier by almost two decades and Mayer by a century," wrote Professor V. Danilevsky, Stalin Prize winner, "Lomonosov saw immeasurably more than either of them. Lavoisier understood only one side of the fundamental law of natural science—the preservation of matter (*the mass*), and he gave no thought to the preservation of energy. A hundred years later Mayer spoke of

the preservation of energy without connecting this question with the preservation of matter. Lomonosov, however, was the first to see both sides of this fundamental law of modern natural science. The law of the preservation of matter and energy must always and everywhere be called Lomonosov's law."

It remains for us to mention the works of Lomonosov in the field of electricity, which refer to the same period.

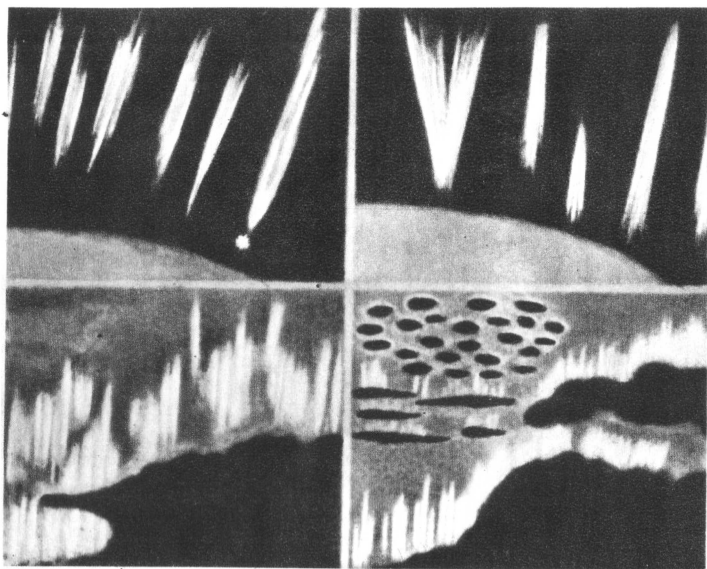
In the middle of the eighteenth century electric phenomena began to attract the attention of scientists in different countries.

Lomonosov devoted much time to the study of electricity and enriched this branch of physics, too, with new and valuable observations and ideas. He conducted many experiments in this field in conjunction with his friend, Academician G. V. Riechman.

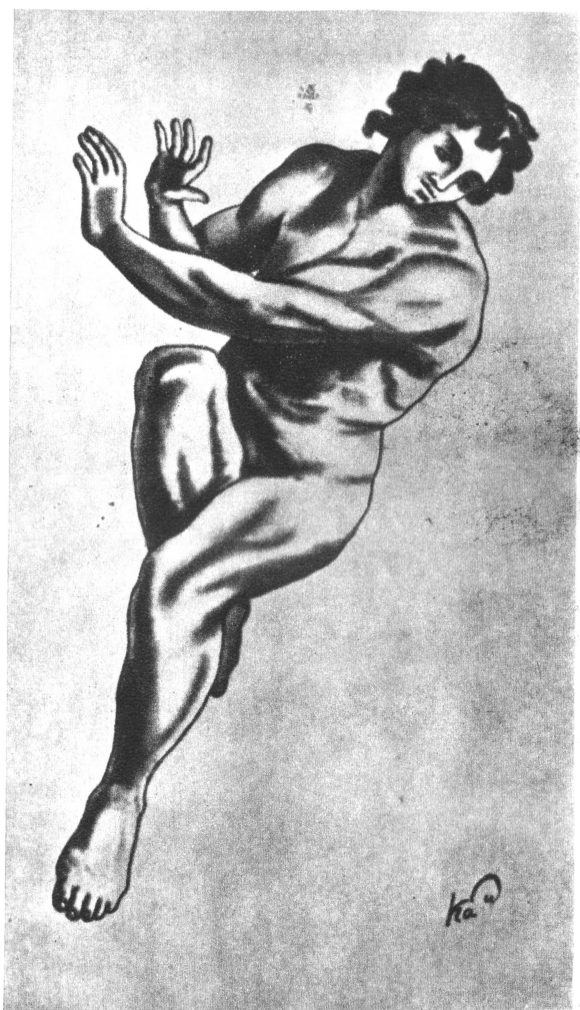
In order to study atmospheric electricity Lomonosov installed on the roof of his house a wooden pole with an iron arrow attached to it. A wire, isolated, as far as possible, from all objects connected to the ground, ran from the arrow to a room. An iron ruler and a silk thread, representing a primitive electrometer, were attached to the end of the wire. A similar "thunder machine," as this arrangement was called in those days, was also installed in the house where Academician Riechman lived.

Soon after he started his experiments with the "thunder machine," Lomonosov made the important discovery that atmospheric electricity exists not only during a thunder-storm. The *Petersburg News* reported in 1753 that "Mr. Lomonosov has discovered that electric power in the air extends further than the sound of the thunder and may exist without thunder at all."

The tragic death of Riechman brought their joint experiments to an end. On July 26, 1753, the day Riechman was killed, he and Lomonosov were present at a meeting



Northern Lights. Sketches by Lomonosov

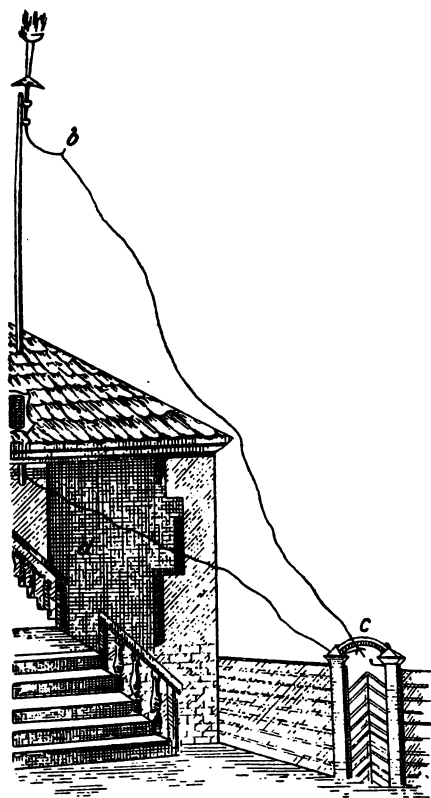


Cain. Drawing by Lomonosov

at the Academy of Sciences. At about one o'clock in the afternoon a huge thunder-cloud appeared in the sky.

Lomonosov and Riechman hastily left the meeting, each hurrying to his "thunder machine." In describing what happened further, Lomonosov wrote: "The thunder was exceptionally loud, and there was not a drop of rain. I inspected my thunder machine but did not see the least sign of electricity. However, when the food was being put on the table I at last saw electric sparks appearing from the wire, and by that time I was joined by my wife and others. Like me they all kept touching the wire and the rod attached to it, as I wished them to see the different colours of the sparks, about which the late Professor Riechman often argued with me. The loudest peal of thunder crashed suddenly at the moment I had my hand near the iron rod and the sparks crackled. Everybody ran away from me. My wife begged me to leave. But curiosity detained me for two or three minutes longer until I was told that my soup would get cold and, besides, the electric sparks had almost ceased to appear. No sooner had I taken my seat at the table than the door was suddenly opened by the late Riechman's servant who was all in tears and breathless. I thought he had been attacked and beaten by somebody on his way to our house. With great difficulty he at last stammered out that the professor had been struck by thunder. I at once rushed to Riechman's house and found him lifeless. His poor widow and her mother were as pale as he was. When I saw him lying dead, and thought of our friendship and accord and that only an hour ago I had been sitting next to him at the conference discussing a declaration we intended to publish, and when I heard his wife and children weeping and thought of my own narrow escape, I was so distressed that I could not reply to the questions of the great crowd that had gathered. He had received the first shock from the hanging ruler on his forehead, where there was

now a bright red spot; the electric power of the thunder had passed from his feet to the floor."



The "electric arrow" on Lomonosov's house

On November 25, 1753, soon after Riechman's death, Lomonosov delivered a report on *The Phenomena of the Air Occasioned by Electric Power* at a public meeting of the Academy of Sciences. In this report he drew attention, for the first time in the history of science, to the

vertical streams of air in the atmosphere, and to the important part played by them in various natural phenomena.

Lomonosov explained that streams of cold air coming down vertically were the cause of the sudden drops in temperature which sometimes follow a thaw in winter. He tried to prove by experiment the presence of such streams in the air by measuring the density of air under various temperatures.

The idea of vertical air currents was suggested for the second time and proved by experiment only by the end of the last century. Now the existence of ascending streams of air is widely known, and it is these streams that pilots use when flying gliders.

Lomonosov explained that atmospheric electricity originated from the friction caused by the movement of vertical streams of air. It was not till 1929 that a theory of the origin of atmospheric electricity, very close to the one Lomonosov had put forward, was developed.

The accident that was so fatal to Riechman induced Lomonosov to propose an original method of protecting dwellings from lightning by diverting "the electric thunder power to a pole with an iron rod on it, which should be installed in an empty space where the thunder could strike as much as it liked."

In these and in later years Lomonosov deeply studied the question of the origin of the Northern Lights, which had stirred his imagination in his boyhood. He quite correctly pointed out the electric nature of this majestic phenomenon. He made beautiful drawings of various views of the Northern Lights, and it is to be regretted that his far-reaching plans of experimental and theoretical investigations which were to be completed by an essay explaining "the origin of the Northern Lights and other similar phenomena," remained unfulfilled and the essay unfinished.

Lomonosov's works in meteorology are closely connected with his research in atmospheric electricity. In this field, too, Lomonosov outstripped his contemporaries by a century. His idea of creating an automatic meteorological observatory and of investigating the upper strata of the atmosphere, which he hoped to carry out by using a helicopter of his own design to bear the instruments, etc., was realized only at the end of the last century.

In summing up Lomonosov's scientific activities in the period between 1749 and 1758, note must be made of the versatility of his scientific work which covered various questions of theoretical and applied physics and chemistry, chemical technology, theoretical and experimental meteorology, and many others.

It is also necessary to emphasize the originality and profundity of his scientific thinking which enabled him to enrich these various spheres of knowledge with discoveries that outstripped his age by a century.

The remarkable law that Lomonosov discovered and which bears his name will tower eternally over all this titanic work as a great monument to the genius of Russian science.



CHAPTER III

The previous chapter was devoted to Lomonosov's scientific work in the years directly following the building of the chemical laboratory. This period lasted up to 1758, from which time he concentrated his experimental work in a private laboratory attached to his house.

In this chapter we shall give a brief description of the main events in his personal life at that time, and some aspects and features of his many-sided activities upon which we have not touched so far.

In 1749 the Academy of Sciences resumed its so-called "public assemblies." These were ceremonial occasions at which the academicians had to speak. Lomonosov was one of the two speakers at the first assembly on November 25, 1749. The audience liked his speech, and from that time he was often invited to speak on similar ceremonial occasions.

The talent of a speaker was now added to Lomonosov's numerous and already well-known talents! There seemed to be no limit to his abilities; he brilliantly fulfilled whatever task he was entrusted with.

It is quite possible that this impression together with his fame as a poet was the reason that when the Russian theatre came into vogue at court and it was found

that there were no Russian plays, the following entry appeared in the register of the Academy: "On this day (September 29, 1750) the President of the Academy of Sciences proclaimed in the name of Her Imperial Majesty a verbal *ukase* directing the President to command Professors Tredyakovsky and Lomonosov each to compose a tragedy."

Lomonosov set to work and his tragedy *Tamira and Selim* was ready in a month. It was published and was evidently successful, for two months later it was followed by a second edition.

In 1751 Lomonosov wrote his second and last tragedy *Demophont*. Although these tragedies did not make the contributions to literature that his investigations made to science, yet the heroes in them express some interesting ideas on civic duty, tyranny, man's right to love, and so on.

To reach the peak of virtue in his span,
Then rest in peace—no nobler fate has man—

says Selim, the hero of *Tamira and Selim*.

Admirers of Lomonosov's poetry tried their best to persuade him to give up his work in physics and chemistry and to devote himself entirely to literature. To satisfy his powerful "patrons" the great scientist had to hunt up excuses in order to continue his scientific investigations. In a letter to Count Ivan Shuvalov, a very powerful courtier who was well disposed towards him, Lomonosov wrote: "As for entirely giving up my exercises in physics and chemistry, there is neither need nor possibility. Every man requires some relaxation from his work. Some people spend their free time with friends or with their families in such amusements as cards, draughts, and so on, others prefer to smoke. But these are all things I gave up long ago, for I found them only tiresome. I trust, therefore, that as rest from my work of compiling

and writing a history of Russia and improving the Russian language, to be allowed to spend a few hours a day on physical and chemical experiments instead of playing billiards. . . .”

What tragic irony! A scientist of genius compelled to find excuses to carry on the experiments that brought glory to his country, by comparing them with a game of billiards or draughts!

At this time Lomonosov completed two treatises which played an important role in the development of the Russian language; these were: *Rhetoric* (1748) and *Russian Grammar* (1755).

Lomonosov deeply loved the Russian language. He described the beauty of his mother tongue in the following picturesque way: “Charles V, the Roman emperor, used to say that one should speak Spanish with God, French with friends, German with enemies, and Italian with women. But had he known the Russian language, I am sure he would have added that this language might be used on all occasions, for in it he would have found the magnificence of the Spanish, the liveliness of the French, the strength of the German, the tenderness of the Italian and above all the richness and the terse expressive beauty of the Greek and the Latin.” •

Therefore, he considered that the main task of his *Rhetoric* was to bring his mother tongue, which “does not yield in natural richness, beauty, and strength to any European language . . . to the same perfection that amazes us in others.”

The purpose of the first Russian grammar was to teach people “how to speak and write a purely Russian language.”

Many generations of Russian people used Lomonosov’s grammar book to study their language. It was published 14 times and translated into the German,

French, and the modern Greek. Lomonosov's grammar served as a model for later grammars.

"Only a great genius like Lomonosov," wrote S. Obnorsky, a linguist and member of the Academy of Sciences of the U.S.S.R., "could create, strictly out of nothing, a work which was applied in practice for nearly 75 years, and whose theoretical premises are still important to science though they had been formulated 185 years ago."

This period was also marked by the start of Lomonosov's activity as a historian. He amassed material on ancient Russian history. His studies into the interpretation of Russian history led him to serious conflict with Academician G. Miller, whose works contained unverified information insulting to Russia. In 1760, as a result of his investigations, Lomonosov wrote a brief description of the main events in the history of Russia up to the time of Peter the Great. He entitled this composition *A Short Russian Chronicle*.

Ancient Russian History, published only after his death, is of greater interest to us, particularly the first part, which is devoted to the origin of the Russian people. Here Lomonosov, for the first time in historical science, paid due attention to the numerous migrations of peoples that undoubtedly had taken place.

Lomonosov's profound knowledge of history and geography and his patriotism are evidenced in his correspondence with Voltaire, the famous French philosopher and historian, in which he pointed out to the latter numerous mistakes contained in his *History of the Russian Empire Under Peter the Great*.

Lomonosov's patriotism made him irreconcilable to the attempts by foreigners in high office at the Academy to hinder the spread of education in Russia. Schumacher, who remained his chief enemy, now often said he had perceived too late his "great mistake in approving Lomono-

sov's professorship." Lomonosov's fame grew steadily while Schumacher was getting old and his influence gradually waned. The intense struggle which Lomonosov had been carrying on for many years, and which had consumed much of his strength and energy, finally ended in victory. The numerous complaints of the academicians against the Academy administration resulted in Lomonosov's appointment in 1757 to the post of Counsellor of the Administration. This gave him the same authority as Schumacher.

Lomonosov investigated all the affairs of the Academy with his usual conscientiousness and endeavoured to eliminate shortcomings wherever possible. This administrative work took up much of his time and greatly impeded his scientific activity.

That same year, 1757, Lomonosov moved to a new house with a private laboratory attached to it. Though seemingly unimportant, this event affected his scientific activity to some extent. Here he was free from all restrictions and could work out the numerous inventions born in his scientific mind. In this laboratory he and his assistants created many apparatus for all kinds of physical research, and a particularly large number of optical instruments.

His plans for extensive administrative reforms at the Academy, the unceasing struggle against his enemies in the administration, and work in his own laboratory, fully took up Lomonosov's time and he lost practically all interest in the activities of the Academy's chemical laboratory that he had founded.

Lomonosov's struggle to eliminate shortcomings in the work of the Petersburg Academy was a manifestation of his deeply patriotic activity directed towards raising the level of culture in Russia and spreading education among the peoples inhabiting the country.

"He loved his people dearly. That is why he carried

on an irreconcilable struggle against scientists who shut themselves up in the blind alley of their own narrow interests," declared an article carried by *Pravda* on November 18, 1936. Personally Lomonosov used to say: "I would not hold it as a sin against anyone for rising even against his own father if he does it for the common cause and especially for the consolidation of science in his country."

Lomonosov's educational activity in this period was marked by his participation in organizing Moscow University, the first university in Russia. Essentially he was its founder, for this university, the greatest seat of knowledge in the country, was built in accordance with his plan.

Moscow University gave the country Herzen, Griboyedov, Stoletov and Sechenov, P. Chebyshev, the famous mathematician, S. Chaplygin, Hero of Socialist Labour, and many other outstanding men.

Lomonosov's plan of the university provided for three faculties: law, medicine, philosophy (at that time the latter included the faculty of natural sciences and the faculty of physics and mathematics). A secondary school was organized at the university.

Moscow University was established on January 12, 1755. Nikolai Popovsky, Lomonosov's favourite pupil, was appointed professor of rhetoric at the university and head master of the secondary school.

A print-shop was set up at the university, and a volume of Lomonosov's works was one of the first books it printed.

In recognition of Lomonosov's services the Soviet Government conferred upon Moscow University the name of its founder.

In conclusion let us stop on the general outlines of Lomonosov's creative work, which reveal his world outlook.

All his scientific activity is permeated with profound philosophic ideas that were usually far ahead of his time. His brilliant scientific works laid the foundation for a materialistic understanding of natural science in Russia. From his first work to the last Lomonosov consistently maintained the idea that practice and theory in science are indissolubly bound up with each other. "A genuine chemist," he wrote in one of his first works, "should also be a philosopher."

Although he considered experimentation to be the source of knowledge, Lomonosov at the same time sharply opposed bare empiricism and excessive enthusiasm for experiments to the detriment of a theoretical explanation of the phenomenon under observation. "For what have the numerous experiments in physics and chemistry been made?" he asked. "To what end have so many great men devoted their labour and exposed themselves to danger and suffering? Is it only for the sake of looking and wondering at great numbers of different things and substances massed together in a confused heap, without thinking about their proper arrangement?"

No, Lomonosov viewed the task of science quite differently. He looked upon experimentation as a means of penetrating the secrets of nature and of wresting them away from her and, further, with the help of theory, of finding "in the inner structure of substances the origin of their visible properties." This was his idea of the duty of a scientist and of the aim of science.

These thoughts fully harmonize with the ideas of another great Russian scientist—Ivan Petrovich Pavlov, the physiologist.

In an address to young men and women, Pavlov said: "... in your studies, experiments and observations try to see not only what is on the surface. Do not turn into collectors of facts. Try to penetrate their origin. Seek insistently the laws governing them."

What were Lomonosov's philosophic views? He was a militant materialist, the founder of Russian materialistic philosophy. He propagated his world outlook not only in his various scientific works and public speeches, but also in his numerous poems.

In his works, Lomonosov consistently maintained the material nature of the surrounding world. Matter, according to him, is that of which a substance is composed and on which depends its essence. And at the same time he said that every process taking place in a substance originates from its essence and nature.

Our perception of the surrounding world is materialistic, too. It is not by our consciousness that the surrounding world is created, as thought by idealist philosophers; it is material objects, existing independently of us, that act on our senses and call forth sensations, which in the human consciousness are turned into an idea of the world.

Here, for example, is how Lomonosov understood the origin of the sensation of sour taste: "The sour matter, contained in the nerves of the tongue, coheres with the sour particles placed on the tongue and produces a change of movement which is reflected in the brain." Here, too, we can see that the material object is primary and the definite perception or idea secondary.

The same thought is formulated with even greater clarity in Lomonosov's definition of an idea. "Ideas," he wrote, "are perceptions of things or actions in our minds; for example, we form an idea of clocks by picturing them in our minds without actually seeing them."

A correct materialistic understanding of the interconnection between consciousness and the surrounding world enabled him to formulate the following remarkable rule for the study of nature: "To establish theories through observations and then to correct observations through theories is the best way of finding out the truth."

In Lomonosov's time materialistic views were shared by many progressive scientists. However, the historic scantiness of science in those days led Lomonosov's contemporaries to recognize mechanistic, metaphysical materialism. Characterizing that period, Engels noted that one of the principal features of its science was "the elaboration of a peculiar general outlook, the central point of which is the view of the *absolute invariability of nature*. In whatever way nature itself might have come into being, once present it remained as it was as long as it continued to exist."

A man of his times, Lomonosov remained a mechanistic materialist in many of his views. However, his genius and passionate faith in the power of the human mind, for which no fetish exists and which fearlessly rejects everything obsolete in science, impelled him to rebel against the idea of the invariability of the world, which was recognized by the greatest scientists of the day. Lomonosov's works contain ideas on the variability of nature and on the continuous processes that cause profound changes in the surrounding world. He appreciated the importance of these ideas and reverted to their proof time and again. Lomonosov refuted the idea of the invariability of nature convincingly and often in a beautiful and sublime form.

"If the chief great bodies of the universe, such as the planets and even stars, change . . . then how can the tiniest particles of our small globe, i.e., the mountains (which seem so enormous to us) be free from changes?" he asked, and, with deep faith in the infallibility of his reply to this question, he boldly developed the theory of the origin of mountains, which was so unusual for his time.

According to this theory mountains did not originate in the shape we now know but formed either as a result of the lowering of considerable portions of the earth's

crust, or as a result of volcanic eruption. Much later these ideas were used in geology. It should be emphasized that in the given case Lomonosov's correct philosophical position led him to a theory which anticipated the further advance of science.

Lomonosov's teaching on the unity of the physical and chemical properties of various bodies and his ideas on the unity of all natural bodies are organically linked with his materialistic world outlook.

While pointing out the possibility of dividing all natural bodies into two classes, organic and inorganic, he, at the same time, noted the features common to both and the qualitative differences between them. The community of the chemical components of all bodies and the community of many laws governing these bodies bring all natural bodies together. In organic bodies, however, the separate "parts are so composed and interconnected as to show that all mutually joined parts as a whole have one and the same causal origin. In inorganic bodies the particles have no causal interconnection other than their intercoupling and arrangement."

The idea of interconnection between the physical and chemical properties of bodies and of the kinship and simultaneous qualitative difference of all natural bodies came from the mind of a genuine innovator in science, who fearlessly paved new ways for knowledge.

It is thus clear that the spirit and nature of Lomonosov's scientific work was organically alien to the ignorant conservatism of ecclesiastical teaching.

Lomonosov sharply protested against attempts to substitute the scientific explanation of natural phenomena by religious interpretation. "He who . . . does not wish to or cannot think," he wrote, "and is unable to understand God's wise work in nature is satisfied with reading the Holy Writ and other edifying books. . . . In return he

will receive God's blessing and win his sovereign's grace. . . ."

He courageously spoke against the ignorance of the clergy. One of the "fathers of the church"—St. Augustine—asserted that there was life only in one hemisphere. Concerning this, Lomonosov's *Letter on the Usefulness of Glass* has the following lines:

If Augustine has erred in this,
Then has he used God's word in vain.
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In Colón's and Magellan's wake
Our ships encircle all the globe:
Of God's great wonders we partake,
New lands, and seas, and streams we probe.

In the same resolute way he championed the teaching of Copernicus, who was so fiercely hated by the church, while Ptolemy's system, which it favoured, was refuted by him with brilliant and broadly appreciated humour.

Once two astronomers who had sat down to dine,
Began disputing o'er their wine.
One said the earth revolved around the sun,
The other that the sun around our planet spun.
Copernicus and Ptolemy they hight,
But 'twas the cook that put the matter right.
The host addressed him, "Art thou versed in stars?
I fear this argument our dinner mars."
He answered, "I am sure Copernicus is right,
Though to the sun I've never taken flight,
But I know well one thing, and this is it:
I've never seen the fire turn round the spit.

A Hymn to the Beard, a satiric poem, appeared in Petersburg in 1757 and was distributed in manuscript copies. It subtly ridiculed the ignorance and the parasitic existence of the clergy. Lomonosov was its author. Alarmed by this bold action the Synod forwarded a petition

to the empress, requesting her "to destroy and publicly burn this abusive libel" and to send the author to the Synod "for due admonition and correction."

Fortunately for Lomonosov no attention was paid to this petition, and the episode passed without consequences. We have mentioned it in order to show how consistently Lomonosov was ready to fight by all possible means everything that he considered a hindrance to the spread of education and the flourishing of science.

Lomonosov's role as an outstanding poet and reformer of the literary Russian language was so great that even a short biography will be incomplete if special attention is not given to this sphere of his creative activity.

When Belinsky, the great Russian critic, referred to Lomonosov's role in the history of Russian literature, he said, "Lomonosov is the Peter of our literature," and that was no exaggeration.

Naturally, Russian literature existed before Lomonosov, and his predecessors in this field were Feofan Prokopovich, a writer who was a favourite with Peter the Great, Kantemir, the remarkable satirist, Trediakovsky, the great philologist, and others. But, as Academician P. Lebedev-Polyansky, a specialist in literature, pointed out, it was namely Lomonosov who "remade the Russian language and Russian verse by imparting to them the form and trend of development best suited to express fully the spirit and character of the Russian people, the magnificence, richness, brilliancy, originality, and the inexhaustible strength of Russian creative genius." We thus have every reason to consider Lomonosov's work in the language field as a new page in the history of our literature.

Lomonosov attached great importance to the national language in the development of the culture of a people.



Moscow University in Red Square, founded on the basis of a plan by Lomonosov. The building is seen on the left. (18th century engraving by Quarenghi)

КРАТКОЕ РУКОВОДСТВО
къ
КРАСНОРЪЧІЮ,
книга перъвая,
въ которой содержи́тся
РИТОРИКА
показу́ющая
общія правила
овоего краснорѣчія,
то есть
ОРАТОРІИ
и
ПОЕЗІИ,
сочиненная
въ пользу любящихъ
СЛОВЕСНЫЯ НАУКИ

Трудами Михайла Ломоносова Императорской
Академіи Наукъ и Историческаго собранія
Члена, Химіи Профессора.



ВЪ САНКТ ПЕТЕРБУРГѢ
при Императорской Академіи Наукъ
1748

The title page of Lomonosov's *Rhetoric*

He considered that the culture of every people should develop on the basis of their national language.

The Russian literary language before Lomonosov's day was too difficult for the people to understand. This difficulty was the result of the interspersion of numerous foreign words in the language during the many centuries of historical development of the Russian state. In the beginning most of the foreign words had been borrowed from ancient Bulgarian (the Church-Slavonic language). Later were added a large number of foreign words which, due to the expansion of trade, had penetrated the Russian language from the West. The outcome was that words borrowed from different languages often followed one another in the literature of that time.

Lomonosov considered that the rich indigenous Russian tongue should be the basis of the Russian literary language. At the same time he strove to incorporate into the living Russian tongue such elements of the literary Church-Slavonic language as had either become closely related with the Russian or, while remaining independent, had preserved their clarity and poetical expression.

The already mentioned *Russian Grammar* (1755) was the fruit of Lomonosov's long years of work on the Russian language. Passionately devoted to his country, he held that the simple and vivid Russian language could be used on all occasions—to carry on any discussion or to express even the most complicated ideas, and, therefore, that a grammar of the Russian literary language was necessary in every branch of human knowledge, in all sciences. "Without grammar," he wrote, "oratory is dull, poetry tongue-tied, philosophy unsound, history unpleasant, and jurisprudence dubious.... All sciences need grammar."

Grammar, Lomonosov pointed out, has both a theoretical and a practical significance. Its theoretical significance lies in the fact that it tells us about the laws of

our language, shows us their orderly system and indicates the peculiarities of the language. The practical significance of grammar lies in that it shows and teaches us how to speak and write correctly and points out the way the literary language should be developed.

At the same time that in his grammar he speaks of the laws of his mother tongue, Lomonosov affectionately emphasizes its richness and expressiveness. "If we find it hard to express something, it is not our language but our own want of skill that is to blame," he wrote.

Lomonosov attached great importance to the role of words in a language. Words, he said, express "things" and not ideas, as idealistic philosophers asserted and continue to assert. Lomonosov was a materialist in his views on the meaning of words and on the development of the Russian language.

According to him "speech is given to man to enable him to communicate his ideas to others."

Consequently, speech plays a tremendous role in the social life of mankind.

People built cities, Lomonosov said, they built ships and fortresses, united to repulse enemies and were able to carry out many other undertakings requiring collective effort only because they could communicate their thoughts to each other through speech. For this reason he made the teaching of speech the philosophic basis of his grammar.

Lomonosov explained the development of language from a materialistic point of view. He said that this development is closely linked with the development of human society and with the growth of culture which, in its turn, arises from the development of the material conditions of the life of people. The language of people in the twentieth century has an incomparably richer and more varied vocabulary than the language of people in the past centuries.

In his grammar Lomonosov defined the Russian literary language as a national language spoken by the entire Russian people inhabiting different corners of their vast country. Even the various dialects did not prevent their understanding each other. Lomonosov contrasted the Russian language with, for example, the German language, which is so disjoined that people living in different parts of the country have difficulty in understanding each other.

Lomonosov held that it was very important to utilize the Church-Slavonic language which, owing to the specific features of Russia's historical development, was very close to the Russian. "If, together with the Russian language," he wrote, "we use our kindred original Slavonic language with care and diligence, we shall alienate the wild and strange absurdities that entered our language from foreign languages."

In his *Grammar* and *Rhetoric* Lomonosov demonstrated the beauty of his native tongue with many folk proverbs and sayings.

From his birthplace Lomonosov had carried away a store of Russian mythology. Myths are legends telling of the ideas that ancient peoples had on the origin of the world, of natural phenomena, and of gods and heroes. Lomonosov made extensive use of mythology in his work on synonyms—words having the same or nearly the same essential meaning—in Russian speech.

Lomonosov coined many words, and in so doing was very careful to see that they conveyed the precise meaning he wanted.

Lomonosov strove to make the literary language clear and understandable to the people, tried to bring it closer to them by basing it on Russian colloquial speech.

His *Russian Grammar* consisted of six sections, or "instructions," as Lomonosov called them. The "instructions" dealt with the general meaning of words, with

the rules of spelling, and the sounds of the Russian language. This was followed by the teaching on parts of speech and syntax.

Referring to the *Russian Grammar*, Academician Davydov wrote in 1855: "When we analyze this grammar now, one hundred years later . . . we must confess that essentially we cannot add anything new to the principles of grammar which the great man from Kholmogori had laid."

We have already said that Lomonosov's grammar has not lost its scientific significance even today.

Radishchev and Pushkin, the great Russian writers, pointed out that Lomonosov had rendered tremendous service by being the "propagator of Russian speech."

Pushkin, who continued Lomonosov's work and also used the living Russian speech as the foundation for his literary works, wrote that Lomonosov had protected the Russian language from foreign influence, which had been particularly strong in the reign of Peter the Great, when German, Dutch, and French words penetrated the Russian language. Pushkin said: "This vogue spread to writers, as well . . . , but, fortunately, Lomonosov appeared. . . . His even, flowery, and picturesque style springs mainly from his deep knowledge of the literary Slavonic language, and from a happy fusion of the latter with the language of the common people."

Mention has already been made of Lomonosov's Russian *Rhetoric*. The tasks of rhetoric, as he saw them, were very extensive. "The language," he said, "with which the mighty Russian state rules a great part of the world is second to no European language for its natural richness, beauty, and power. And there is no doubt that it can be brought to the same perfection that amazes us in others."

Lomonosov's *Rhetoric* was thus more than a simple manual of eloquence.

Before Lomonosov's day rhetoric was strongly influenced by the church. It was taught in the seminaries in Latin and not in Russian. But Lomonosov wrote his book in Russian for large circles of readers. The *Rhetoric* contains practical instructions on how to construct speech correctly and attractively, and how to express thoughts logically and clearly. Like his grammar, Lomonosov wrote his *Rhetoric* on the basis of the living Russian language and brought out all its richness.

Many pages of this book are interesting for their ideological content. As examples of eloquence Lomonosov chose for his book those that dealt with the republican system of government, freedom, the struggle of different peoples for their liberation, and so on.

His *Rhetoric* was very successful. We can well understand that for it was the first book on eloquence written in Russian, besides containing an interesting exposition of Lomonosov's outlook on poetry.

Lomonosov found no essential difference between poetry, i. e., rhythmically built speech, which gives rise to a feeling for the beautiful, and prose or oratory built according to the demands of eloquence.

"Speech," the great scientist wrote, "can take the form of prose or verse." The only difference between them lies in the method of organizing speech, but both are able to interpret the phenomena that surround man. Lomonosov held that everything may be described either in verse or by ordinary speech. "One and the same thing can be set forth in prose and verse," he said.

Lomonosov thus extended the circle of themes in poetry and in literature and brought poetry closer to life.

He considered art real only when it is a national, heroic art, which glorifies the might of the Motherland, the valour of its heroes and the fame of its people.

We are indebted to Lomonosov also for the creation of the science of Russian literary style, the foundations of which have retained their significance up to our time. In this work he based himself on the practical demands made on the language by various sciences, and on a careful study of the specific features and history of the Russian language.

In the *Russian Grammar, Rhetoric* and in other works in this field, Lomonosov recognized the similarity between the Russian and the Church-Slavonic languages. Originally he thought that the Russian language of his time had developed as a result of a gradual evolution of the Church-Slavonic language. Later, however, he arrived at the conviction that the ancient Russian and the Church-Slavonic are entirely independent languages. Historical development had brought these two languages into close contact which lasted for several centuries. He pointed out that as a result of this many words had become common to both languages.

In addition, certain words belonging essentially to the Church-Slavonic are understandable to the Russian people. And, finally, there are words belonging exclusively to each language.

On the basis of these facts Lomonosov established three styles for the literary Russian language.

He considered that words common to both the Russian and the Church-Slavonic should form the foundation for the language. These words, he said, with the addition of only not very obsolete words belonging expressly to the Slavonic language but understandable to the Russian people, would produce a "high style."

The "middle style," Lomonosov pointed out, consisted of words common to both the Russian and Slavonic languages, with the addition of words of the high and low "styles." And, finally, the "low style" would be formed on the basis of purely Russian words. In the

"low style" he permitted using a certain number of words of the "middle style."

Lomonosov also indicated the spheres in which the styles he had established should be applied.

Lomonosov wrote that the high style must be used for public speeches, heroic poems, and odes.

The middle style should be used for writing historical compositions, tragedies or friendly messages in verse.

And, finally, the low style was to be used for writing comedies, songs, and letters.

In creating these styles Lomonosov admitted the temporary significance of his theory. He realized that a language could not be created once and for all because of its constant development. He knew that in the course of its development the Russian language would gradually clear itself of all ancient Slavonic words.

Lomonosov was thus the creator of the Russian literary language. A Russian historian aptly defined Lomonosov's merit in this sphere, when he said, "Before Lomonosov, a Russian, seeking to express ideas born of knowledge, experienced a very unpleasant feeling—he felt as though he were mute." Lomonosov helped him to begin speaking in a rich, strong and beautiful language!

Besides being a philologist, Lomonosov was also a remarkable poet.

His poetical talent amazed foreigners; they could not see how one man could be so versatile. For a long time foreign authors wrote that Russia had two Lomonosovs: one—a chemist, and the other—a poet.

His many poetical works show that Lomonosov devoted much attention to literary work and attached great importance to it.

The characteristic feature of his poetry was its lofty ideological content. He could not stand poetry for the sake of poetry.

"I do not see a poet in one who writes trifles. I want to see a citizen in him, pointing out iniquities," he wrote.

He made great demands on a poet.

"A perfect poet," he taught, "must be sufficiently versed in all sciences and thoroughly know and be skilled in many of them. It is not enough for a poet to wish to delight people when he cannot teach them anything."

By rejecting the requirement of an equal number of syllables in the lines of a verse—syllabism—as incompatible with the Russian language, Lomonosov completed the reform of Russian poetry which Tredyakovsky had started. His syllabo-tonic versification, which is based on a regular alternation of stressed and unstressed syllables, is still in use.

Lomonosov's rich and forceful poems are permeated with boundless love for his country. In his literary activity, as in his scientific work, he served his people and country.

Lomonosov approached poetry as a patriot of his country, a thinker, and a scientist.

For him it was a means of spreading knowledge. In his literary works he brought together poetry and science. His poetry is replete with natural scientific themes and ideas on nature and its investigation.

The ode, now almost a bygone, was in particular harmony with his talent. It was a difficult and complicated form of verse, dedicated to some solemn event, or to a prominent person. In the eighteenth century the ode was regarded as a beautiful and refined genre of poetry, which, dedicated to special themes, was usually

written with great inspiration and feeling. Lomonosov's odes occupy a distinguished place in the history of Russian literature.

Lomonosov wrote odes throughout his literary activity, which lasted more than twenty years.

But as his poetic talent developed, and his philosophic and scientific erudition broadened, the character of his odes began to change, while retaining their principal feature. His odes helped him to disseminate knowledge, to propagate science, art, labour, love for his country and to educate Russian society.

In a panegyric dedicated to Empress Elizabeth, Lomonosov showered complimentary epithets on her, calling her "divine," "glorious," "a goddess," etc., in an effort to suggest to her that her glory would be still further enhanced if she established . . . a university in Petersburg!

That beauty may sweet Russia crown,
Our youth will gather from the country round
To study science in fair Peter's town.

A very important patriotic content lay behind the flowery, eulogistic surface of Lomonosov's odes. Through them he taught tsars and infused them with ideas that he considered correct.

For example, in his odes he spoke of the need for a fleet and a regular army, and of spreading education; in them he described his great Motherland and her inexhaustible natural resources. He likewise pointed out the immediate tasks of the country.

Lomonosov trained the rising generation and taught them to treat science with profound respect and to love their country.

Human labour should be peaceful and creative and the life of the people happy. He disapproved of

predatory wars which cause so much suffering, especially for the peasants, whom Lomonosov dearly loved.

He rejoiced in his country's greatness, in the vastness of her expanses, and in her glory.

How joyful is our Russian land!
Her glory overtops the sky,
Her vast domains a fortress stand
Too vast to compass with the eye.

But for the happiness and prosperity of a people favourable conditions are needed for the development and burgeoning of the sciences. Lomonosov constantly spoke of this, and his attention was always focussed on the question of the development of the sciences that Russia needed.

The young from science wisdom reap,
The old find lasting pleasure in it.

These words of his are well known.

Lomonosov's genius, as we have already said, cannot be regarded as a mosaic composed of the various manifestations of his tremendous talent. The diverse aspects of his genius remind us rather of the different facets of a precious stone, whose sparkle is simultaneously reflected by all the facets, while these, in their turn, shine not only with the light thrown back by each but also with the rays mirrored by all. In Lomonosov's creative life, poetry and science are fused in a like manner. Many of his "purely scientific" compositions were poems in prose devoted to scientific themes, and many of his poems were scientific theses.

Lomonosov himself considered his poems a part of his scientific work. In 1753, when proving the priority and originality of his views about the source of the Northern Lights, he declared that, "besides all this, my

ode to the Northern Lights, written in 1743 and published in 1744 in the *Rhetoric*, contains my long-standing opinion that the phenomenon of the Northern Lights is caused by a movement of the air."

His famous *Letter on the Usefulness of Glass* is another example of a scientific essay in verse. Popularizing science in this remarkable work, Lomonosov wrote:

A wise astronomer toiled vainly all his life,
Ensnared in cycles till Copernicus arose,
Of ignorance one of the greatest foes,
And in the centre of the planets placed the sun;
Revealed the course the planets run.
Once round the axis—constitutes a day,
Once round the sun—a year has passed away.
His solar system did the cycles then displace,
The accuracy of his facts did prove his case.

Lomonosov's scientific poetry was a singular phenomenon in the history of human culture. It undoubtedly impelled the dissemination of education in Russia.

His love of his country was the reason for the prominence he gave in his poetry to the personality of Peter the Great.

His poetry idealized Peter. Lomonosov did not notice the negative points in Peter's activity, for he was mainly concerned with the tremendous reorganizational work that this tsar had carried on for the benefit of his country.

In trials he never bowed his head;
Forever shine his well-earned fame!
And Russia rudeness overcame,
Arose, and followed where he led.

The greatness of Russia! That was in what Lomonosov saw Peter's service. And it was with pride in his

country that he addressed the following to Russia's ill-wishers:

Assize the vastness of our land,
Read of our deeds in any book:
And you will see and understand
That no intruders will we brook.

And against the background of the greatness of his country, the idea of human happiness, of the happiness of the people stands out vividly in Lomonosov's poetry, as though it were in the focus of a magnifying lens.

Belinsky called Lomonosov's poetry a hymn to man. All that Lomonosov created, he created for his people, for his country.



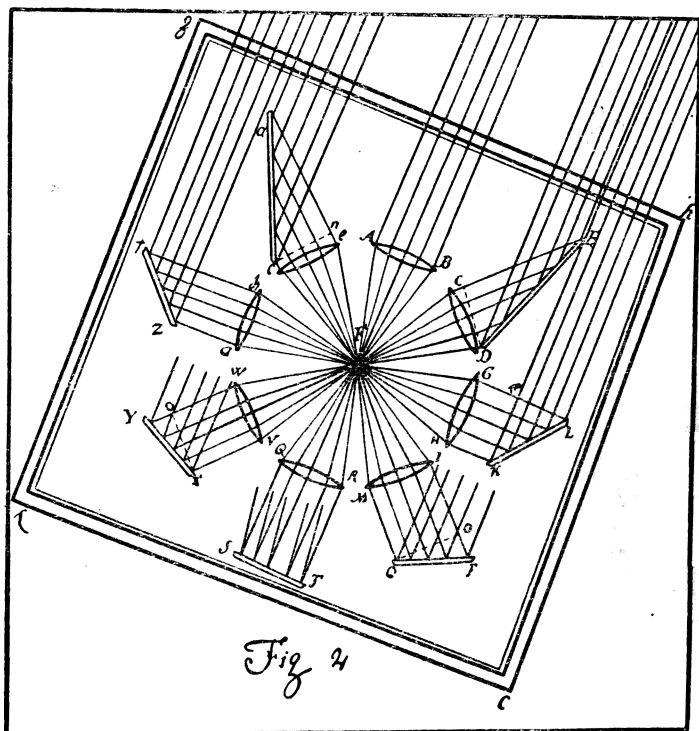
CHAPTER IV

The last period of Lomonosov's life, embracing the years following the building of his private laboratory and up to his death, is characterized by a further extension of his activities. His amazing energy did not relax with age, but seemed to grow as the years passed by. His interests became even more varied. To his scientific and poetic writings of previous years were now added a teeming administrative activity and extensive economic and historical research. In these years we see Lomonosov as a talented designer who made many original physical apparatus.

He paid especial attention at this time to the teaching on light, or optics, which he enriched not only with apparatus of his own invention, but also with the formulation of an original theory on light.

Optics had always interested Lomonosov, especially in his last years. Shortly after returning from abroad, Lomonosov presented to the Academy of Sciences his *Discourse on the Incendiary Catoptrico-Dioptrical Instrument*, which, besides containing an original solution of the question, showed that he was well acquainted with the literature on optics of his day. The instrument described in this composition consisted of several mirrors

and lenses arranged to let the rays of the sun fall on one point and set alight combustible substances. There are grounds to believe that in those years Lomonosov



The drawing of Lomonosov's instrument for producing fire by converging parallel sunrays

intended to continue his investigations in optics, but circumstances prevented him from realizing this desire.

The building of a private laboratory enabled him to start on the invention of optical instruments, of which he created more than ten.

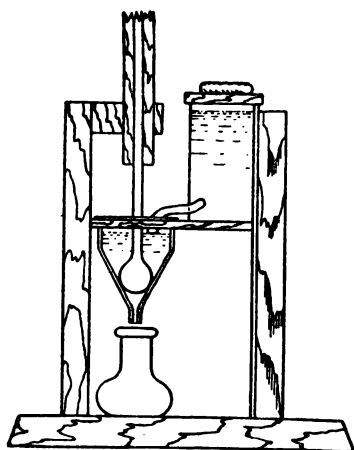
It can only be bitterly regretted that Lomonosov's contemporaries did not understand the significance of all this creative work. The instruments he invented were lost and even their designs have not been preserved. Lomonosov's work in this field can be reconstructed only by his rough notes.

We shall endeavour to describe the most important instruments he invented. At a conference of the Academy of Sciences in 1756, Lomonosov demonstrated a spy-glass intended "to distinguish rocks and ships at night."

Lomonosov called this invention "a night spy-glass." The academicians who examined the new spy-glass very carefully became convinced that "an object, placed in a dark room, may be distinguished through the spy-glass more clearly than without it."

But the fate of the "night spy-glass" was as sad as that of many of Lomonosov's other remarkable works. The "scientists" of his day did not understand his idea, and accused him of trying to attribute magic qualities to the spy-glass. From a scientific point of view, they said, this was absurd. As a matter of fact, Lomonosov had stated only that his spy-glass enabled objects to be made out more clearly in a poor light, and that this had been proved by experiment. His opponents did not allow for the circumstance that at twilight and at night the human eye works differently than by daylight. A spy-glass intended for night observation should have the largest possible object-lens, while the eyepiece should be very small, not exceeding the size of the pupil of the human eye in the dark. The prejudiced and, evidently, sharp objections irritated Lomonosov, and indeed, it was difficult to remain calm in the dispute, when his opponents, driven by a passion to refute his discovery at all costs, "argued so heatedly that seeing they saw not and hearing they heard not."

This biased criticism led to the rejection of Lomonosov's invention and it was soon entirely forgotten.



Lomonosov's apparatus for determining the viscosity of liquids

Lomonosov devoted much time and labour to the construction of a reflecting telescope of a new design that he had invented. As often happens, this remarkable invention was essentially very simple. The usual Newtonian telescope has two mirrors: a large concave mirror at the base and a small plane mirror in the upper part of the tube. The small mirror is placed in the path of the rays falling on the telescope and prevents a part of them from reaching the large mirror. Furthermore,

in Lomonosov's time, people did not know how to make good plane mirrors. Lomonosov placed the large mirror at an angle to the axis of the telescope, thus making the small mirror unnecessary. Lomonosov's telescope had better optic properties as nothing stood in the way of light rays. By slightly changing the construction, Lomonosov succeeded in considerably improving the telescope's quality. As usual, he did not stop short at theory alone, but made a new instrument which he showed to his colleagues at a meeting of the Academy of Sciences in 1762. A telescope of the same system was constructed much later by Herschel, the well-known astronomer, and is now unjustly known as the Herschelian telescope. This instrument which is now widely employed should be called the Lomonosov-Herschel telescope.



Marble Bust of Lomonosov, sculptured by F. I. Shubin, 1792

Serenissimae ac Potentissimae Imperatricis
 ELISABETHAE AVUSTRAE
 totius Russiae Imperatoris

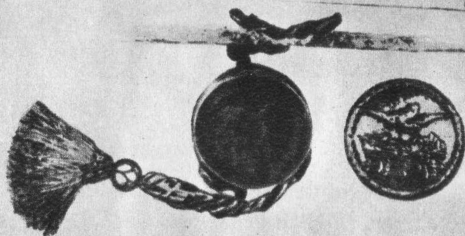
EGO CYRILLUS COMES DE ARSUDOWSKY
 Minoris Russiae ad utramque Boristhenis ripam
 ac legionum trans caracasas
 Helmanus

Nec non S. S. M. Cancellarius ordinarius
 Academiae Imp. Scientiarum Praesens
 nobilem pastorianorum Smolovensium Prodrubunus
 ordinumque Aquilae Albei Alexandri et S. Annae Equo
 pro potestate ab AUSTRIA mibi concessa

Dn. Consiliarium Mich. Lomonosoff
 Chymiae Professori ora.
 Communi totius Academiae Perpropositionalis suffragio
 Collegam hujus Societatis
 saltem hoc Diplomate declaro
 in cuiusque iure et emolumento
 nostro ordini AUSTRIAE beneficio attributo
 confero

Petropoli a. c. m. dccc. die Mart. m. v.

Comes de Rasnitsyn



M. V. Lomonosov's Diploma as Academician, 1751

Lomonosov's interest in geographical investigations, particularly in nautical expeditions, prompted him to design and make various optical instruments for navigation purposes. In this sphere, too, his genius told in the working out of simple and original instruments and methods to determine the position of a ship at sea. For this work he had to make astronomical observations, and became so proficient in this field that he was soon able to make an important discovery.

On May 26, 1761, the entire scientific world observed with great interest a very rare astronomical phenomenon. On that day Venus, which moves in an orbit situated between the Sun and the orbit of the Earth, had to cross the line between the Sun and the Earth. In this movement Venus is seen as a small dark disc against the background of the Sun. Such passages by this planet are very rare; the next passage after 1761 will take place only in 2004. For astronomers this phenomenon was very interesting, as by measuring the time that Venus took to pass across the Sun's disc they could calculate exactly the distance between the Sun and the Earth.

The Petersburg Academy of Sciences organized special expeditions to observe this phenomenon. Observations were conducted in Petersburg, too, and Lomonosov was among the observers.

While watching Venus' passage Lomonosov noticed that when the edge of the planet approached the Sun's disc, the latter lost its usual sharp outlines at the point where it came into contact with the planet. And as Venus passed across the Sun's disc and approached the opposite edge "a swelling appeared on this edge; the closer the planet drew to the end of its passage the clearer this swelling became. Soon this swelling vanished and Venus suddenly appeared to have no edge. When the planet had completed its passage, in other

words at the moment that it lost contact with the Sun, the edge of the latter again became vague."

This phenomenon was seen by everyone observing Venus' passage, but Lomonosov was the only one among them to understand correctly its significance. "These phenomena," he wrote, "led Counsellor Lomonosov to the conclusion that Venus is surrounded by an extensive atmosphere, similar to (if not greater than) that which envelops our globe."

Thus we see that Lomonosov discovered the existence of an atmosphere around Venus several scores of years before any European scientist and made this discovery generally known.

It has been pointed out already that in his scientific work Lomonosov always kept to the rule of never separating practical experimentation from theory, as he considered them to be indissolubly connected and complementary to each other. This is also true of his activity in the sphere of optics. His talent for broad generalizations enabled him to work out an original theory on the nature of light.

When the teaching of light first came into being there appeared two seemingly irreconcilable views on the nature of light, and it was necessary to make a decisive choice between them. Isaac Newton, the English philosopher and mathematician, who was the author of one of these theories, considered that light was a stream of material particles—so-called light corpuscles. Meanwhile, Christian Huyghens, the Dutch natural philosopher and mathematician, who was Newton's contemporary, offered the theory that light was not a stream of particles, but a wave movement of a specific substance—ether. Huyghens considered that in the ether waves of light drift apart from a luminous body in the same way that waves drift apart on a smooth surface of water

when a stone drops into it. In Huyghens' opinion ether is so mobile and tenuous that unnoticeably it fills up the whole of space surrounding us. We do not notice ether just as we do not notice still air around us.

Scientists had to choose between these two theories, and in Lomonosov's day they were more inclined to consider Newton's views as correct.

Lomonosov courageously rejected Newton's theory and offered a theory of his own, which, though closer to Huyghens' views, was essentially different from them.

The further development of science showed that Lomonosov's theory, like the theories of Newton and Huyghens, was wrong, and that is why a detailed description of it would be superfluous. It is interesting to note, however, that a characteristic feature of Lomonosov's views on the subject was that he took account of the interaction between light and substance. Great importance is attached to this interaction today, and it needed Lomonosov's genius to anticipate this by two hundred years.

Towards the end of his life Lomonosov again took up a field of science for the study of which he had been sent abroad twenty years before. In 1761 Lomonosov sent to the publishers a work entitled *The Elements of Metallurgy or Mining*, and it was only in the summer of 1763 that the book was finally published. The main part evidently had been written shortly after Lomonosov had returned from his studies and consisted of a description of metallurgy in the form that he had studied it in Freiberg. This part of the book shows that Lomonosov had acquired a good knowledge of mining, but unlike his other works, *Metallurgy* does not contain any original ideas "typical of Lomonosov" and, therefore, is not very interesting.

Lomonosov, however, made some additions to *The Elements of Metallurgy*, which, in contrast to the book itself, are extremely interesting.

The first addition, dealing with the "free motion of air in mines," was written in 1745; the second, devoted to geology and entitled *On the Layers of the Earth*, was written probably towards the end of the 1750's. At a meeting of the Academy of Sciences in those years Lomonosov delivered a report *On the Earthquake Origin of Metals*. This and the preceding work contained many similar ideas.

These last works of Lomonosov, which represent the first Russian essays on geology, require a more detailed analysis.

As in all his activity, Lomonosov was induced to take up research into geology and metallurgy for two reasons: his purely scientific interest in these spheres and his constant concern for the welfare of his country. "It is a great thing," he wrote, "to penetrate with our minds the bosom of the earth which nature is guarding against our hands and eyes."

The bosom of the earth contains metal ores, and "the army, trade, navigation, and other state undertakings in Russia all demand metals."

Lomonosov's views on geology were based on the idea of the variability of the world we live in, which, as we have pointed out, was revolutionary for his day. "It should always be borne in mind," he wrote in *On the Layers of the Earth*, "that when the visible physical bodies on the earth and the entire world originated they were in a different state to what we see them in now; they passed through great changes.... Many people vainly think that everything we see had been made by the Creator at the beginning; they think that mountains, meadows, and waters, as well as various kinds of minerals, appeared together with the whole world. Therefore, they say, there is no need to investigate the reasons why minerals are found in different places and have different inner properties. Such reasonings are

extremely harmful to the development of all the sciences and, consequently, they are harmful to the gaining of a knowledge of nature and, especially, to the science of mining, although for such clever people it is easy to be philosophers when they have learned by heart the words 'that is how God created things,' and then use them to explain everything."

To sustain his idea of the variability of nature Lomonosov put forward data on the finding in various parts of the earth's surface of the fossils of plants and animals. He refuted as incorrect the opinion that such fossils were fortuitous freaks of nature, and was the first in world science to point out the similarity between the chemical composition of the fossil shells of animals and the chemical composition of the shells of similar animals existing today.

The unusual shape of many fossils was in itself enough to suggest the idea of the variability of the world. However, Lomonosov offered more reliable proof of the changes that had taken place on the earth. He carefully examined fossil plants that had been found in cold climates, and discovered among them remains of plants that could grow only in hot tropical climates. From this observation Lomonosov drew the correct conclusion that "in ancient times the northern regions had a very hot climate."

Lomonosov did not confine the variability of nature to climatic changes, and the changes connected with them that took place in the animal and vegetable kingdoms. He was the first to indicate the variability of rocks and minerals and the very slow, but incessant physical and chemical processes taking place in the earth's crust. It was not until many years later that these views became widespread. That gives full grounds for considering Lomonosov the founder of the science dealing with the physical and chemical processes taking

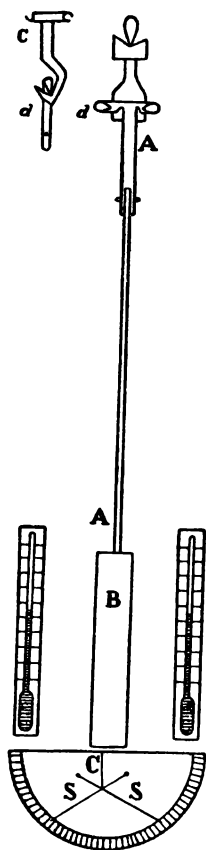
place in the earth's crust. Later this science was called geochemistry and was developed only in the twentieth century through the efforts of another prominent Russian scientist, the late Academician Vernadsky.

Lomonosov viewed the structure of the surface of the globe as being closely connected with the structure of its internal parts. He wrote that the earth's surface and its upper layer in general "are parts of the lower strata from which they borrow much and to which they also give much of their own." Therefore, the variability of the earth's surface is connected with the processes taking place inside the globe.

Let us consider what forces cause changes on the earth's surface. Lomonosov was perfectly right in believing that the activity of wind and water is one of the causes of the variability of the earth's surface. Evidently when still a boy he had noticed the "great changes in the banks and fairways . . . as a result of spring floods."

Lomonosov considered earthquakes to be the second cause of the variability of the earth's surface. Brilliantly anticipating truth he correctly appreciated the role of earthquakes in the life of the earth. He left the science of his day far behind when he boldly asserted that "not a single place

under the sun is completely free of earthquakes." To this it must be added that he likewise attributed "the slight



The big pendulum designed by Lomonosov for registering changes in gravitation

and gradual lowerings and risings of the earth's surface" to earthquakes. Modern science has proved with highly sensitive measuring instruments that Lomonosov had been right. We now know that slight dislocations of the earth are being observed in every corner of the globe without exception.

-- In his book Lomonosov described various kinds of fuel, such as coal, peat, oil-shales, and so on. Although the mining of these minerals in noticeable quantities was started much later in Russia, he said that "there can be no doubt that Russia has peat."

His views were that the formation of peat and coal was the result of the decay of the remains of vegetation. The idea of the vegetable origin of combustible minerals, which is now standard, was offered a second time and consolidated in science considerably later.

As a final note to this short description of Lomonosov's researches in geology, it must be mentioned that in this field, too, he strove to apply the methods of chemistry, physics and mathematics.

"The bosom of the earth," he wrote, "is made up of layers and veins of different materials, conceived by nature in its depths. When people examine their various positions, colour, and weight, may I suggest that in their work they be guided by mathematics, chemistry, and physics in general."

This behest of Lomonosov's is being carried out to-day by all investigators of the earth.

In 1763, shortly before his death, Lomonosov set down the outline of a capital work, in which he intended to "list and describe the ores and other minerals in all Russian mines; and from this to work out a general system of Russian mineralogy and to suggest . . . rules of prospecting and features indicating the presence of ore."

The plan Lomonosov worked out for compiling a book on Russian mineralogy was unusual for the time.

To receive the information he needed, Lomonosov wrote to the owners of "different mines and diggings" requesting them to send him samples of ores and minerals. "The wrapping of every specimen," he explained, "should have a number written legibly, and the enclosed lists should indicate in the greatest possible detail the location of the minerals, especially the depth at which they had been found."

Lomonosov died without having carried out his intention. Only in Soviet times did it become possible to carry out Lomonosov's plan and now his dream has been realized in the multi-volumed *Minerals of the U.S.S.R.* and *Mineralogy of the Urals*.

"Many proofs," he wrote, foreseeing another discovery that was made only in our times, "lead me to the conclusion that in the cold north, too, there is tremendous mineral wealth; and there is no one to seek this treasure!" The world now knows of the immense mineral riches discovered by Soviet scientists in the extreme north of the Soviet Union. Suffice it to mention the incredible changes that have taken place in the Kola Peninsula as a result of the development of the Khibiny mining industry. The apatite ores mined there are processed into phosphorous fertilizers which are used in the boundless fields of our country.

Lomonosov belonged to the type of scientist who finds no difficulty in working simultaneously in different branches of science. The wealth of ideas and the speed with which he mastered every new problem enabled him to work with unfeigned interest in various spheres of science at the same time. It is not surprising then that when in 1758 he was appointed chief of the Geographical Department at the Academy of Sciences, he devoted himself enthusiastically to an activity entirely new to him.



Lomonosov's grave in Alexandro-Nevsky Monastery in Leningrad



Monument to Lomonosov in front of the new buildings of Moscow
University on Lenin Hills

The Geographical Department was mainly concerned with the drawing up of correct maps of Russia. But before Lomonosov's appointment the department carried on its work unsatisfactorily. Lomonosov, with his usual energy, soon set things going and, under his direction, the department had nine maps ready for publication by 1763.

In drawing up new maps Lomonosov applied the method he had worked out for compiling *Russian Mineralogy*. At his urgent request "the Senate ordered reliable and detailed geographic information to be sent to the Academy of Sciences from every town of the Russian state." Lomonosov personally pointed out the kind of information he needed, saying that it had to include the "size of the town, how many brick and wooden buildings it had, the name of the river or lake it abutted on, the dates of its fairs, a list of its trades and crafts, factories, works, mills, adjoining forest and arable land, on which side was the upland bank of the river, what landing-stages it had, when the rivers froze and thawed, the distance to the nearest towns, the location of high mountains, the kind of grain mostly sown and which give best harvests, etc."

Replies began to arrive from different towns soon after the questionnaires were sent out, and these had to be examined and catalogued. It is easy to see how this compiling method would have given a picture of the country's general economic condition, but death prevented Lomonosov from carrying out this big-scale work, and the information he had amassed was not turned to account.

Lomonosov's plan "to show the possibility of sailing to the East Indies across the Arctic Ocean," which he had worked on earlier, was allied to his activities in geography.

Lomonosov had thought of a possible northern passage early in life. In 1752 he wrote:

In vain does rugged nature try
To hide that region from our eye,
Where stands the Orient's northern gate.
For through the ice-packs I can see,
A Russian Colón fearlessly
Forge on in spite of hostile fate.

This thought did not leave him till the end of his days. He carefully studied the reports of different Polar expeditions and studied the nature of the Arctic Ocean in an effort to find an ice-free route to Japan, America, and India. He spoke to fishermen and traders who sailed the northern seas, patiently questioning them on sailing conditions, the boundaries of ice-fields and the temperature at different seasons. On the basis of this careful study of the Arctic Ocean he arrived at the conclusion that the northern passage should lie between Spitsbergen and Novaya Zemlya. Convinced of the correctness of this conclusion, Lomonosov submitted to the Admiralty in 1763 a plan of a north sea route. After long procrastination it was decided to send an expedition, which, strangely enough, was ordered to take a route lying between Spitsbergen and Greenland, and not the one indicated by Lomonosov.

Lomonosov was firmly convinced that the only ice-free route was the one he had pointed out and not the one the expedition was ordered to follow. Nevertheless, appreciating the value of a Polar expedition, he shared most actively in fitting it out. He again started to collect data on the Arctic Ocean, drew up instructions for the commanding officers of the expedition, and saw that the vessels were provided with everything they needed for the voyage and for scientific observations and measurements.

The expedition was destined to put out to sea after Lomonosov's death. The expedition, commanded by Admiral Chichagov, set out on May 9, 1765, and spent two years trying to find a way through the ice to Japan. When it was finally satisfied of the impossibility of passing between Greenland and Spitsbergen, it returned to Archangel.

In 1871, 107 years later, an Austrian Polar expedition discovered an ice-free sea exactly where Lomonosov had said it should be.

After his appointment in 1757 to the post of Counsellor of the Academy Administration, Lomonosov devoted much of the time we are reviewing here to improving the work of the Academy. He personally felt the close bond that united his work with the Academy. There is a story that during an argument, Shuvalov, the influential courtier, shouted at Lomonosov: "I'll have you thrown out of the Academy." And Lomonosov proudly replied: "Not unless you throw the Academy out of me."

In his last years, Lomonosov worked hard to set in order the activity of the Academy's secondary school and university.

The life of the pupils of the secondary school was so hard that a certain number was always on the deserter's list. The school building was half-ruined and totally unsuitable for studies. "In winter," one of the school inspectors wrote, "the teachers, dressed in overcoats, pace up and down the classroom during lessons, and the pupils, who are not supplied with warm clothes and are not permitted to rise from their seats, shiver with the cold; scabs and scurvy break out among them, compelling them to stop attending classes."

By the end of 1764 Lomonosov succeeded in getting suitable premises for the school and university at the price of protracted petitioning. To bring order into the

life of the school pupils, he worked out special rules of conduct. These rules advised the pupils "to be very diligent in their studies and not to succumb to any temptations." The rules made provision for all eventualities in a pupil's life. For instance, they pointed out that "if a pupil is asked by the teacher to repeat his lesson and he does not know it well, his class-mate, sitting next to him, should not prompt him, lest this should encourage laziness."

Lomonosov gave the school and university his constant care and improved their work. In the short period that he headed the secondary school it was finished by 20 pupils, whereas not a single pupil had finished it in all the years it had been under Schumacher's "direction."

The work of the Academy's university, too, improved through Lomonosov's efforts. All his petitions, however, to have the latter organized into a real university, on the model of Moscow University, remained unanswered. Both the secondary school and the university did not long survive Lomonosov.

In conclusion, mention must be made of a work that Lomonosov wrote towards the end of his life, in which is revealed the purpose that had guided all his activity. In everything he did—whether it was experimentation in physics or chemistry, writing poetry or geographic investigations—the impelling force behind it was his patriotic striving to work for the benefit of his country. This striving was most vividly manifested in a remarkable work, *On the Growth and Preservation of the Russian People*, which he wrote in 1761. Here Lomonosov shows himself as a wise statesman, mapping out measures to improve the life of the people and to increase the country's population.

In this work Lomonosov urged his countrymen to wage a struggle against infantile mortality and to increase the medical aid given to the population.

Lomonosov intended writing a few more works on similar subjects. Here are some of their titles: *On the Elimination of Idleness, On the Improvement of Morals and Manners and on Greater Dissemination of Education, On the Improvement and Multiplication of Crafts and Industries, On the Improvement of Agriculture, On the Improvement of State Economy*, and so on.

Lomonosov was unable to carry out his intentions, but the plan of his activities, that he left behind him, clearly shows that the welfare of his fellow-countrymen was uppermost in his mind to the end of his life.

When we read this remarkable plan of work it puts before us in all its beauty the splendid image of Mikhail Vasilyevich Lomonosov, who was a scientist of genius, a great humanist, and one of the best sons of the Russian people.



CHAPTER V

The bitter privations of his youth, the terrific mental strain that his work required, and his dogged struggle against "the enemies of Russian science" finally told on Lomonosov's sturdy health. He ailed often in the 1760's and became painfully irritable. His collisions with I. Taubert, the "worthy" successor of Schumacher at the Academic administration, and with other academicians became sharper and more and more frequent.

Summarizing, as it were, his long years of struggle against mismanagement at the Academy of Sciences, Lomonosov began to write his famous *Short History of the Behaviour of the Academy Administration*, in which, with his characteristic frankness, he described the unseemingly conduct of Schumacher and his friends.

He worked out detailed Statutes of the Academy of Sciences. In this work Lomonosov was guided not only by a desire to criticize, but also to achieve the conditions necessary for normal work at the Academy.

The main task of the Academy, as Lomonosov saw it, was to assist in every possible way the economic and cultural development of Russia. This institution should be a national Russian institution and the academicians should be "native Russians." The administration should be put into the hands of the academicians. This, he

said, would end the rule of the all-powerful Academy administration.

Lomonosov's plan was not approved, although after his death many of the suggestions it contained were implemented.

During the last few years of his life Lomonosov's fame spread far beyond the borders of Russia. In 1760 he was elected honorary member of the Swedish Academy of Sciences. In 1761, as though replying to this recognition of his services, Lomonosov submitted to the Swedish Academy a remarkably "Lomonosovian" work entitled *Reflections on the Origin of Icebergs in the Northern Seas*, which contained ideas so distinctively pertaining to him.

Here he correctly explained the origin of ice-fields and icebergs. He said that ice-fields form in the mouths of big rivers emptying into the northern seas, and that icebergs originate near steep shores.

Today it may be taken as proved that icebergs are formed when huge masses of ice break away from glaciers sliding down the steep shores into the sea. This work, in which Lomonosov correctly pointed out the origin of an interesting and important natural phenomenon, was printed in the Swedish language in 1763 in the *Transactions of the Swedish Academy of Sciences*.

Soon after this Lomonosov's great service to science was again publicly recognized. At a solemn ceremony held on October 10, 1763, he was elected honorary member of the Academy of Arts, which had been established in 1757.

On March 12, 1764, the Italian journal *The Florentine Scientific News* printed a long article that gave a detailed description of Lomonosov's works.

Shortly after this article was printed, Lomonosov received a letter from Zanotti, Secretary of the Bologna

Academy of Sciences, who informed him in flattering terms that in appreciation of his services to science, the Bologna Academy of Sciences had on April 13, 1764, elected him to honorary membership.

Lomonosov's scientific work was known in almost every European country, and his theses or references to them were printed in the Russian, Latin, German, French, Italian, and Swedish languages.

Russia was the only country that failed to recognize him. He keenly felt the full injustice of this position and bitterly wrote: "I am made to suffer only because I want my people to be educated so that they would be able to show their worth."

Lomonosov's position considerably deteriorated as a result of the political changes that took place in Russia at this time.

Empress Elizabeth, who had favoured Lomonosov, died at the close of 1761. The weak-minded Emperor Peter III, who succeeded her, did not reign long. A coup d'état at court placed Catherine II on the throne on June 28, 1762. Peter III was murdered.

Lomonosov's influential "patrons," Vorontsov and Shuvalov, fell into disgrace. Lomonosov's worst enemies, including Taubert, whom he hated, came to power.

Lomonosov saw that he could no longer count on any support for his undertakings, and in 1762 handed in his resignation, which, however, was not accepted. Catherine II did not understand the importance of Lomonosov's scientific work and did not appreciate his activities. Furthermore, she looked upon him as an adherent of the party headed by Shuvalov and Vorontsov, and was not averse to getting rid of Lomonosov altogether.

On the other hand, as she claimed to be an "enlightened" ruler, she could not disregard Lomonosov's

fame in Europe. All these circumstances explain the inconsistency of her actions.

In 1763 Catherine II unexpectedly issued an *ukase* on Lomonosov's resignation, only to demand his return a week later. Affecting to favour Lomonosov, the empress visited his home in 1764 and, as the *Petersburg News* reported, "was pleased to inspect his mosaics . . . a number of physical instruments that he had recently invented, and watched some physical and chemical experiments." But in spite of this, all his plans for important administrative and scientific undertakings found no encouragement and remained unfulfilled.

Lomonosov saw that while formerly, though it had cost him great effort and perseverance, he had succeeded in carrying out some of the plans which he thought were especially important, now the wall of hostility and incomprehension that surrounded him gave him no hope that the plans he was working on would ever be realized.

Euler, who understood how important Lomonosov was for Russia, wrote about him to the President of the Academy of Sciences: "This man of genius is as much a credit to the Imperial Academy as he is to the whole nation."

Incessant conflicts with his opponents and the consciousness that it was impossible to bring to life his cherished plans and reforms contributed towards a further worsening of his health. In 1764 he took to bed for a long time with a serious illness. There was a period when his friends were alarmed for his life. However, his iron constitution overcame the illness, but did not throw it off altogether. Sometimes he kept indoors for weeks on end. The illness caused him great suffering: his legs swelled and sores appeared on them.

In the early spring of 1765 Lomonosov caught a bad cold and was again confined to bed. His condition wors-

ened from day to day. On his death-bed he worried greatly about the fate of his life's work. His friend, Academician Y. Shtelin, who was constantly at his bedside, related that a few days before he died, Lomonosov sadly said: "My friend, I see that I must die, but I am taking my death calmly; it does not worry me. My only regret is that I have been unable to complete everything I undertook for the welfare of my country, for the development of science, and for the fame of the Academy. And now that my life is ending I can see that all my plans will disappear together with me."

Mikhail Vasilyevich Lomonosov died on April 4, 1765, at the age of 54. He was buried in the cemetery of the Alexandro-Nevisky Monastery in Petersburg (Leningrad).

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Nearly two centuries have passed since Lomonosov died. Looking back we can appreciate how much his activity benefited the Russian people and see what happened to his work.

The best people of Russia have always given Lomonosov his due. "Lomonosov was a great man," Alexander Pushkin wrote. "He founded our first university. To be more exact, he himself was our first university." V. G. Belinsky, the great revolutionary democrat and literary critic, who highly appraised Lomonosov, wrote: "Lomonosov shone like the Northern Lights on the shores of the Arctic Ocean. This phenomenon was dazzling and beautiful! It went to prove that a man is a man in any condition and any clime, that genius can triumph over all the obstacles that an inimical fate places in its path, and finally, that a Russian can achieve the great and the beautiful."

But were there any followers of Lomonosov's traditions? Had he any disciples who continued the work he had begun, and who supported his traditions?

This question is often answered in the negative. But that is not true. Lomonosov did have pupils who continued to develop those features of his scientific work which later became typical of the best representatives of Russian science.

Among them were S. Rumovsky, S. Kotelnikov, and A. Protasov, all students of the Academic university, who had studied directly under Lomonosov and had felt the impact of his genius. Lomonosov valued Rumovsky's abilities. "I can certify," he wrote, "that Stepan Rumovsky, who, among other students, attends my lectures with great diligence, gives the cleverest answers to my questions."

And though in later years Lomonosov's relations with his pupil were spoiled, Rumovsky appeared as his successor. Rumovsky was widely known beyond the borders of Russia as an astronomer. Carrying on Lomonosov's traditions, he devoted much of his attention to applied sciences and to popularizing knowledge.

S. Kotelnikov, a gifted mathematician, contributed much to the dissemination of science in Russia. He translated the mathematical works of Euclid, gave public lectures, published chronicles, etc. Like his teacher, Kotelnikov readily undertook problems of great practical importance. For instance, he shared actively in drawing up a plan for connecting the Don with the Volga.

A. Protasov, the third of Lomonosov's pupils mentioned above, was a physician and biologist and carried on a many-sided activity. He devoted much energy to publishing chronicles, directing the work of the Academy's print-shop, its engraving department, etc. The older generation of Lomonosov's pupils passed on his tradi-

tions. The pupils of Rumovsky and Kotelnikov, the well-known travellers I. Lepyokhin and B. Inokhodtsev, were both men of many-sided interests. Inokhodtsev worked on a plan for connecting the Volga with the Don, and contributed largely towards fixing the exact geographic position of various places in Russia. Lepyokhin enriched our knowledge of the fauna and flora of our country, and studied folk medicine.

Later, the Lomonosov trend in science was represented by V. Severgin, a mineralogist and chemist, and N. Ozeretskovsky, a prominent biologist, who took an active part in spreading public education by helping to establish schools and universities in Russia. Severgin wrote many valuable works on mineralogy and chemistry. He contributed much to the investigation of Russia and also took part in compiling an academic dictionary of the Russian language.

There is a continuity of ideas between Lomonosov and the best Russian scientists of the 60's and later years of the nineteenth century. We find Lomonosov's traditions in the works of Lobachevsky, Zinin, Tsenkovsky, Butlerov, Pirogov, Botkin, Mendeleev, Sechenov, Stoletov, the Kovalevskys, and Mechnikov. The works of these scientists, in their turn, firmly connect Lomonosov with our day.

Evaluating the role Lomonosov played in the development of our country, Academician S. I. Vavilov said: "The influence of his genius and work is immeasurable. Our language, our grammar, poetry, and literature stemmed from Lomonosov. Our Academy of Sciences owes its present existence and significance to Lomonosov."

Many of Lomonosov's cherished ideas were realized only in our time.

Great changes have taken place in Denisovka (now called Lomonosovo), the village where the great scien-

tist was born. Two schools have been opened there: a middle school and a school for artistic ivory-carving. The cultural needs of the population are attended to by a library. The village has a medical station, a cheese dairy, and a butter dairy. An artel of artists in ivory-carving produces beautiful and delicate articles of walrus tusk. The Soviet people take a great interest in the life of Lomonosov, and the Lomonosov Museum is always full of visitors.

Lomonosov's memory is highly honoured in the Soviet Union, and many of the country's enterprises and educational institutions have been named after him. Special Lomonosov readings are arranged to acquaint students and large circles of the Soviet public with the achievements of modern science, and with the remarkable investigations of Lomonosov.

"When in response to the call of the Government and the Party," wrote Academician Vavilov, "our modern science and technique began to develop rapidly, it was the sprouting of the seeds sown by Lomonosov. The terrible war, the struggle for our very existence, demanded a still greater mobilization of our science—physics, chemistry, and geology. If we look back with attention, it will become clear to us that the achievements of our science were laid in the past by Lomonosov."

B. N. Menshutkin, who studied the works of the great scientist, was quite right when he applied the verse translated by Lomonosov from Horace to Lomonosov himself:

An edifice I've raised of lasting glory;
O'ertopping pyramids, more strong than metal.
The rage of Boreas it will withstand
And all the ravages of time eternal.
Not all of me will die—a goodly portion
Will live when I have shuffled off this mortal coil

An immortal memorial to Mikhail Vasilyevich Lomonosov is the establishment in the Soviet land of thousands of higher and secondary schools and scientific institutions which work "to spread science and make it flourish in the country"—a cause to which Lomonosov, the great son of the Russian people, had devoted his whole life.

